FEBRUARY, 1960

Welding Journal

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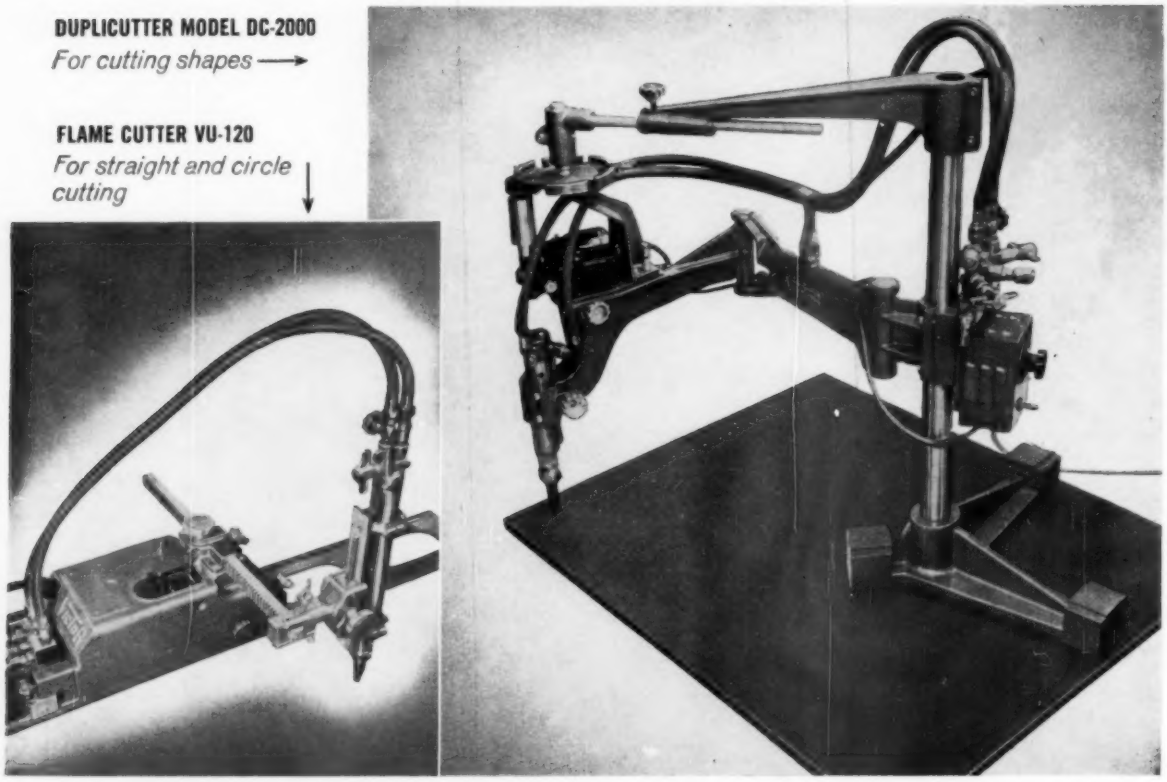

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PRESS-TIME NEWS ...about ...People ...Welding ...Products

AWS Missiles and Rockets Group Outlines Activities

A high degree of lively interest has centered in the activities of the Missiles & Rockets Welded Fabrication Committee recently organized by the AMERICAN WELDING SOCIETY. There are many reasons for this. In general, the production and development of rockets is of deep national concern and, in particular, welding is challenged to make a most accurate determination of the ultimate strength and reliability of the welded joint. Rocket components require the highest possible strength-to-weight ratios. Specifically, the reproducibility and the reliable efficiency of the welded joint in rocket motor cases have been questioned and more costly methods of fabrication have been pursued in order to avoid, especially, the longitudinal seam.

This situation gave rise, last June 9th, to the endorsement by the AWS Board of Directors of the special Committee on Missiles and Rockets Welded Fabrication. The first meeting was on June 10th in New York City, and Donald B. Howard, American Car and Foundry, Division of ACF Industries, Incorporated, New York City, New York, became its chairman. Vice chairman is Francis H. Stevenson, Aerojet-General Corporation, Sacramento, Calif. Byron Gates of the Budd Company, Philadelphia, Pa., is serving as Secretary. The second meeting was held Sept. 30, 1959, in Detroit. At that time, four working subcommittees were formed as follows: *Welding*—chairmanned by William H. Downing, Boeing Airplane Co., Seattle, Wash. *Metallurgical*—headed by Donald Kinsey, U.S. Steel Corp., Pittsburgh, Pa. *Design*—is led by Russell Libert, A. O. Smith Corp., Milwaukee, Wis. *Quality Assurance*—is coordinated by John Jakubowski, General Electric Co., Philadelphia, Pa. Each of these groups has met once and another round of meetings is scheduled for February 1960. The main Committee is to meet again on April 26th in Los Angeles, Calif.

As a result of the work done to date, the committee had decided to focus attention on the various problems experienced by fabricators engaged in current production. In addition, the present area of investigation will be limited to those heat-treatable steels in the 200,000 to 230,000 psi yield-strength range. In this connection, the emphasis will be placed on finding the highest optimum combination of physical properties rather than attempting to determine ultimate values. This type of program not only avoids duplication of work by other groups engaged in future development but affords a realistic chance of an early achievement.

The committee has discovered a real need for the free exchange of technical information among the fabricators in the interest of national defense. For this reason, and in order to keep the efficiency of the committee at a high level, mutual exchange of such information is being emphasized. Members of the committee are expected to be contributors rather than observers. It is expected that these goals will help to attract funds for weldability research, will stimulate the interchange of applicable knowledge and will encourage the cooperation of all concerned—from the designer to the welder.

Glasier Made Vice-President

O. H. Glasier has been appointed executive vice-president of Air Reduction Sales Co., New York, N. Y., it was announced by R. E. Lenhard, president. Mr. Glasier has been with Airco since 1936 and most recently held the office of vice-president—gases.

Signs of the Times

As one of the unmistakable "signs of the times" indicating the growth of the welding industry, there has been published recently what is reported to be the first mail-order catalog ever to appear in this field. Issued by the Saginaw Welding Supply Co., Saginaw, Mich., catalog No. 9 (106 pp., $8^1/_2$ x 11) is a comprehensive book which is being distributed to welders and small job shops throughout central and northern Michigan.

This new approach in marketing and distribution will make more readily available to the small purchaser any of the 500-odd items illustrated, described and indexed.

The Distributor's Future

At the recent Fort Worth, Tex., meeting of the National Welding Supply Assn., R. W. Raney, sales manager for A. O. Smith Corp., glimpsed the future of the welding distributor in the "Soaring 60's" by raising pertinent questions and suggesting the answers.

Mr. Raney suggested that a more effective relationship is obtained between manufacturer and distributor when the latter chooses to creatively market a single line of item rather than use the supermarket approach. He stressed the advisability of associating with manufacturers who maintain substantial research operations and of feeding them information on customer needs and desires.

R. W. Raney

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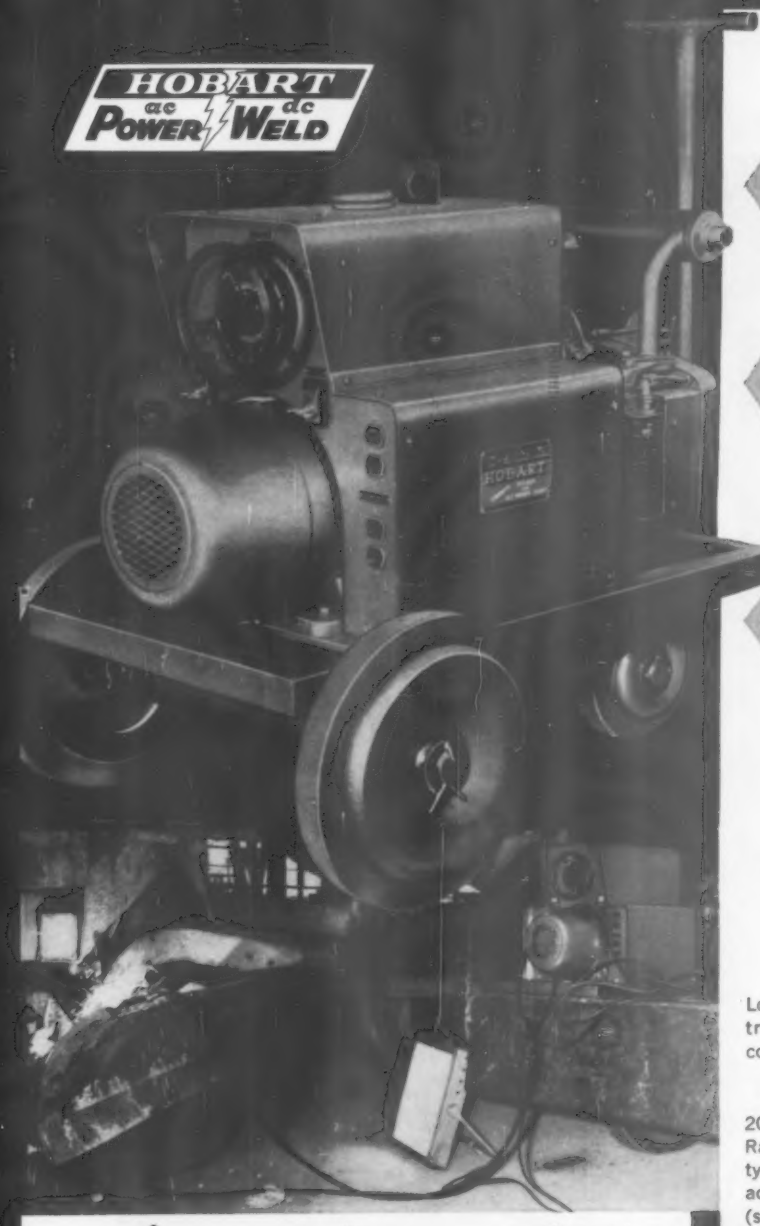

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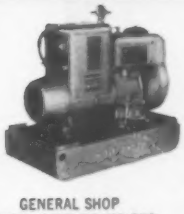

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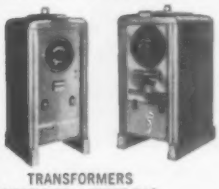

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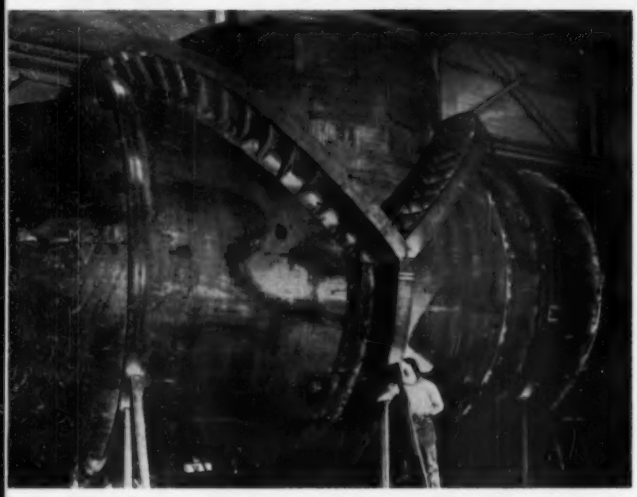
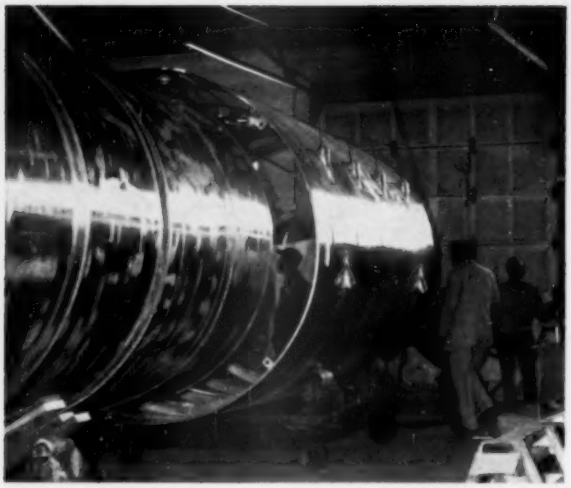
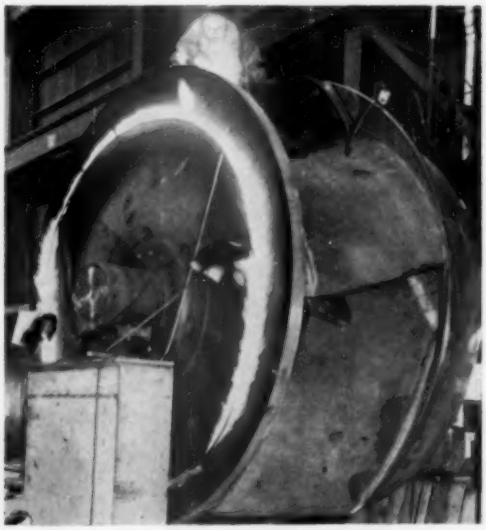


This 14-ft diam weldment is part of a 90-ft header pipe to be used in Detroit's water system project to replace gravity flow by pressure in the raw-water supply link. The weldment was made by the Steelweld Division of R. C. Mahon Co., Detroit



The all-aluminum liquid-oxygen carrier, shown above during fabrication by Beech Aircraft Corp., is constructed from aluminum alloy 5083. The container assembly, called a Dewar, consists of two concentric tanks separated by a 6-in. vacuum space which is filled with an insulating material. (Courtesy Kaiser Aluminum & Chemical Corp.)

This 50 x 30 x 24-ft structural steel frame weighing 20 tons was designed and welded by the R. C. Mahon's Steelweld Division. Acting partly as a boom, partly as a gantry, the structure will swing the huge 10-bucket digging wheel of a 2100-ton, 150-ft high, continuous strip-mining machine



Continuous preheat is applied to this huge, reversible pump-turbine impeller made by Allis-Chalmers for the New York State Power Authority's Tuscorora plant. Reported the largest of its kind, this weldment is a pump when driven by its 37,500-hp motor and a 28,000-hp turbine when operating under a 75-ft head

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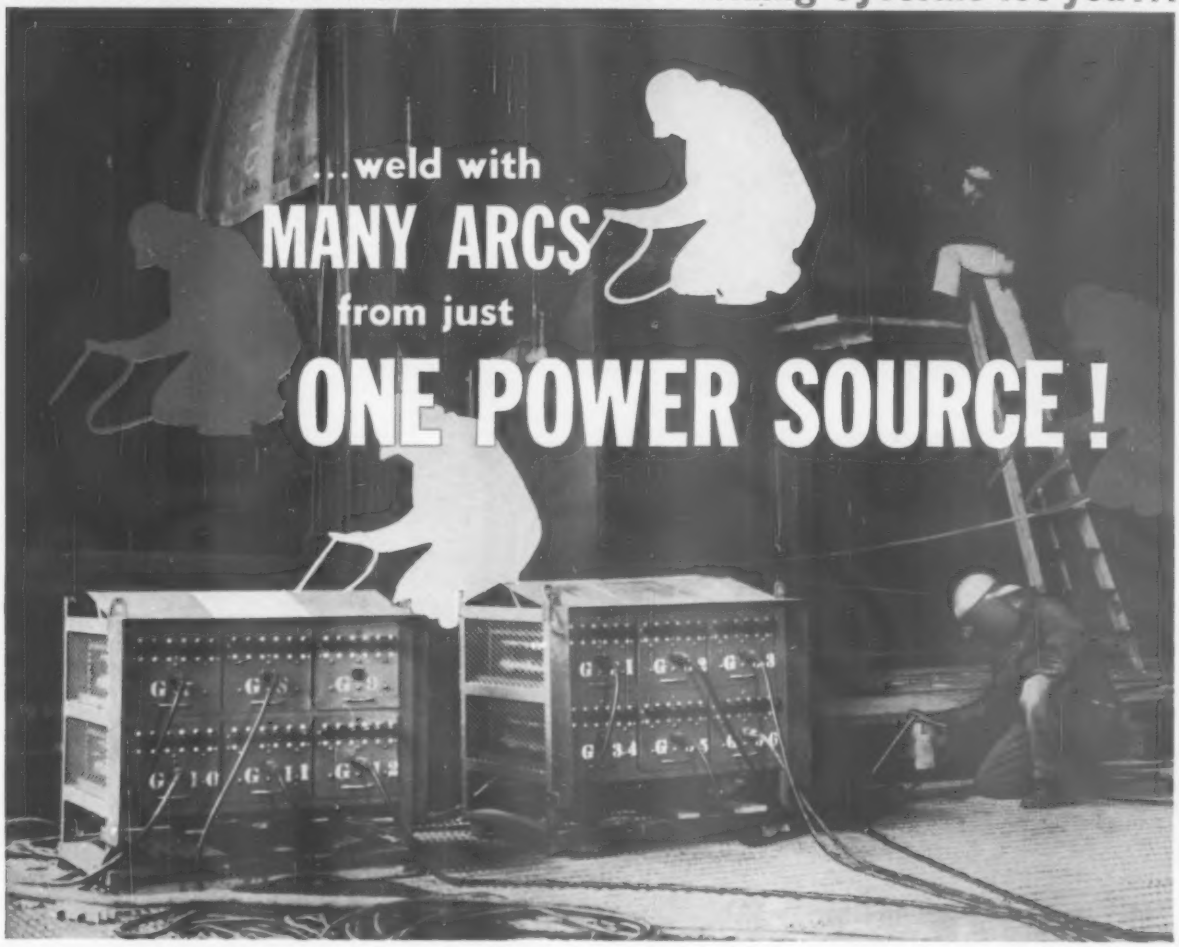

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WORLD-WIDE WELDING NEWS

by Gerard E. Claussen

AUSTRIA

Schweisstechnik (Vienna) vol 13, reports that the No. 1 welding problem in steel construction today, according to Dr. L. Seltenhammer of Vienna, is brittle fracture. Without contributing new data, he summarizes four outstanding procedures for evaluating weldability; namely, those proposed by Hauttmann, Houdremont, the IIW, and Kloppel. All rank steels in order of suitability for increasing severity of service, the most comprehensive ranking being Houdremont's. He stresses the susceptibility of the steel to aging.

BELGIUM

Fillet Welds Tested

The Belgium welding magazine *Revue de la Soudure*, for the second quarter of 1959 contains an account of research on welded steel girders with a longitudinal plate fillet welded to the split web along the neutral axis. The work was performed at Liege University and was sponsored by the Belgium Committee for the Study of Steel Structures. The girders were 6 ft long, and loads up to 400 tons were applied. The girders were designed not for practical use, but for evaluating the strength of fillet welds under combined normal and tangential tensile stress. The results showed that fillet welds designed for combined tension and shear with the aid of conventional formulas are larger than need be.

Besides several reports from the IIW, including a report on fatigue fractures in welded oil tankers, this issue described a British firm's experience in welding aluminum. Thicknesses up to 6 in. were welded successfully with consumable electrode, argon and a preheat of 390° F. Base metal and wire were held to 0.01% Cu, max., to maintain high corrosion resistance.

Dr. GERARD E. CLAUSSEN is associated with Arcrods Corporation, Sparrows Point, Md.

EAST GERMANY

Leipzig Fair

The East German welding magazine, *Schweisstechnik* for June 1959 consists mainly of a 36-page description of welding exhibits at the 1959 Leipzig Trade Fair. There were exhibits from all Soviet countries as well as Sweden, Belgium, France and West Germany. Half of the article deals with exhibits of welded cranes, agricultural machinery, trucks and railway rolling stock. The other half describes equipment, for example: (*a*) An hydraulic oxygen cutting machine. (*b*) Arc metal spray guns. One gun sprays 33 lb of steel per hour at 400 amp, 30 v using flat or drooping characteristic power supplies. Two 0.079-in. wires are sprayed. Although Russia is said to lead in this field, they sent no models to the Fair. (*c*) A micro-seam welder for electronic tube fabrication. (*d*) Medium-frequency a-c generator, 300 to 450 cycles, 3000 rpm, no slip-rings or brushes. The arc is very elastic and is free from magnetic blow. (*e*) A 207-kva shipyard rectifier for 20 operators, inductive regulation, 60 v open circuit. (*f*) Two types of submerged fluxes; sintered fluxes for crack-free welds on sheet metal, and an electric furnace product made from lime, manganese slag and fluorspar.

Study Trip to Russia

Dr. Werner Gilde and Alexis Neumann of the Central Welding Institute in Halle report on a study trip to Russia, Sept 3–23, 1958. Their four outstanding impressions were (*a*) submerged arc welding with extremely high current densities or plate electrodes, (*b*) electroslag welding, (*c*) CO_2 welding, (*d*) tubular structures. At Zniitmasch in Moscow, electroslag and friction welding were seen. CO_2 welding wire contained 0.7–1.0% Si, 1.5–2.0% Mn. At the Bauman Institute there were demonstrations of ultrasonic welding and roller stress relief of welded seams in sheet metal.

Prof. Rykalin's machine for testing the sensitivity of weld metal to hot cracks was seen. At the Moscow Industrial Fair a magnetic-flux arc-welding machine of Brown Boveri type with 0.032 in. wire was on display. The Paton Institute in Kiev demonstrated a brittle-fracture specimen consisting of a butt weld under tensile stress and struck an impact blow. The strength of welded tubular connections at −78° F was shown to vary from 26,000 to 57,000 psi, depending on design. In Baku the petroleum industry was visited in order to learn about the planned Russia-East German pipe line. Artificial islands of welded tubular construction in the Caspian were visited. In general the root bead is manual, succeeding layers being submerged arc welded.

WEST GERMANY

Various Techniques

The May 1959 issue of the West German Welding magazine *Schweissen und Schneiden* contains articles on the welding of power piping, oxyacetylene piercing, brazing of steel and time study. The article on piping emphasized the necessity of a neutral flame in oxyacetylene welding $2^1/_4$% Cr − 1% Mo piping. Forming gas (nitrogen +8% hydrogen) inside the pipe was helpful for the root pass in oxyacetylene and tungsten argon-arc welding. Joint design is discussed in detail.

The article on piercing describes a procedure for cutting holes in carbon steel up to 6 in. thick. The technique involves opening the oxy-

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gen valve as slowly as possible after the surface has been melted. By moving the torch slowly forward as the oxygen valve is fully opened, the hole is cleared of slag and piercing is completed. A hole was cut in 6-in. steel in 1.10 min.

A new type of brazing rod is described in the article on brazing. The rod consists of four strands of brazing wire twisted together with borate flux in between.

The time-study article provides tables and graphs on time of welding, stub loss and weld size for butt and fillet joints welded with covered electrodes.

Joint Design

Two new West German standards on joint designs have been issued. DIN 2559 shows a V, a U and a V-U joint design for power piping. DIN 8551 provides six joint designs for deep-penetration electrodes and eleven designs for submerged-arc welding. DIN 44-753 (March 1959) provides standard nomenclature for the mechanical, electrical and operational aspects of spot, seam and projection welding. The German Standards Association has an index of over 500 DIN standards that have been translated into English. The index is free of charge and the translations can be purchased at the same price as the German originals.

Also, a West German machinery journal *TZ Fur Prakt. Metallbearbeitung* published 34 photographs of welded presses up to 400 tons pressure. Presses with hinged upper arm instead of a solid C frame are particularly adapted to welding requirements.

ITALY

Studies by Italian Institute

The January 1959 issue of the Italian Institute of Welding's magazine, *Rivista Italiana Della Saldatura*, describes tests on the flexibility of arc welding cables. Flexibility was expressed as the damping coefficient, the cable swinging as a pendulum. The elasticity of the cable was a minor factor compared with bonding forces between molecules, and between copper and insulation. Defects in submerged-arc welds are described in another article. They are classified as those due to: (1) oil, water, etc. in the joint; (2) extraneous materials in the flux; (3) incorrect joint design; (4) incorrect location of electrode; (5) incorrect off-center position in girth welds; (6) incorrect technique; (7) incorrect combination of flux and electrode; (8) base-metal defects. An interesting ternary diagram relates current and voltage to flux-wire ratio.

The Institute's Subcommittee A, on hydrogen in weld metal, found wide variation in total water in the coating of low-hydrogen electrodes and in diffusible and residual hydrogen in the weld metal due probably to differences in storage conditions in the different laboratories. Besides verifying these results, the Subcommittee will investigate the relation between micro-cracks and hydrogen in the electrode. Subcommittee C, on weld-metal tests, is investigating the effect of interpass temperature. Subcommittee D, on deep penetration electrodes, is determining the best angle of bevel for use with these electrodes. Subcommittee E, on classification of electrodes, is studying a classification system for electrodes for welding cast iron.

RUSSIA

Welding Studies

In the May issue of *Svarachnoe Proizvodstvo*, Russian equipment for welding reactive metals in inert gas or vacuum is described by members of the staff of Bauman Institute. An elaborate trailing shield is used for inert-gas welding.

The welding of mild and low-alloy steel with CO_2 required an electrode (0.079 in. diam) containing 0.10% C, 0.94% Si, 1.52% Mn, and 0.04–0.07% Al. Tensile and impact properties were satisfactory. Slag amounted to 0.3 to 1.2% of the weight of the deposit and contained 4% FeO, 10–20% MnO, 50–40% SiO_2, 36% Al_2O_3. The inclusion content of the deposit was 0.009–0.014%, which was lower than with cored electrodes or submerged-arc welding.

The distribution of temperature was calculated and measured in the vicinity of fillet welds made by the submerged-arc process in low-alloy steel $^5/_{32}$ to 1-in. thick. A parabolic relation was found between the ratio of the thickness of the two plates of the joint and the distance from the weld at which a given maximum temperature was reached in each plate.

Under-water Research

The volt-ampere characteristics of the arc from a refractory-covered steel electrode were measured under water 6- to 33-ft deep from 190 to 400 amp. As the arc was lengthened from 0.08 to 0.39 in., the voltage of a stationary arc rose from 21 to 40 v., while the voltage of an arc moving $^3/_4$ ipm rose from 20 to 47 v.

SWITZERLAND

Compressed-gas History

In *Journal de la Soudure* (vol.49), the president of the Swiss Welding Society, Dr. P. Schlapfer, reviewed the history of calcium carbide and compressed gases in Switzerland. The first carbide furnace was installed in 1895, and the first oxygen plant in 1897. The latter electrolyzed water and required 15 kwhr to produce 35 cu ft of oxygen.

NETHERLANDS

Erection of the welded highway bridge across the Rhine at Rhenen *(Courtesy IIW)*

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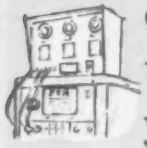

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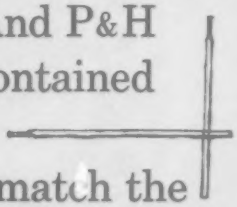

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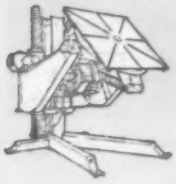

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Welding—Agent of Progress

In a speech to the House of Representatives on April 10, 1959, Congressman Frank C. Osmers, Jr., presented an outstanding summary of the achievements of welding. Throughout the nation, state governors and city mayors signed proclamations designating the month of April as *National Welded Products Month*. Window displays featuring welded products were prominent. These things all combined to give the public a small glimmer of awareness about how much we depend on welding. This was the first step in what must be a long and vigorous education campaign.

We engineers know that welding is vital to today's industry and economy. We know that in many cases it is not only the best way, but the *only* way. We know how welding progressed from the first stumbling efforts at gas welding to today's efficient, automatic electric processes. We've seen gaps in our technology close as the welding of aluminum, magnesium and even titanium became commonplace practices.

Unfortunately, the public—and even engineers in other fields—have not been kept aware of this remarkable progress and its importance. They take the products for granted without realizing that modern homes and appliances, industrial machines, missiles and nuclear power plants exist because welding has made them possible. Many don't even know what welding is. Most know nothing of the great variety of processes.

To know the story of welding ourselves is not enough—we have kept it hidden from the public too long. The public should know that the vast array of shiny metal necessities and conveniences that surrounds them is made possible by welding. It is our job to spread this story.

We now have a vehicle, *National Welded Products Month*, and we have the knowledge. Let us all get behind this project and make the month of April synonymous with welding.

H. E. Rockefeller
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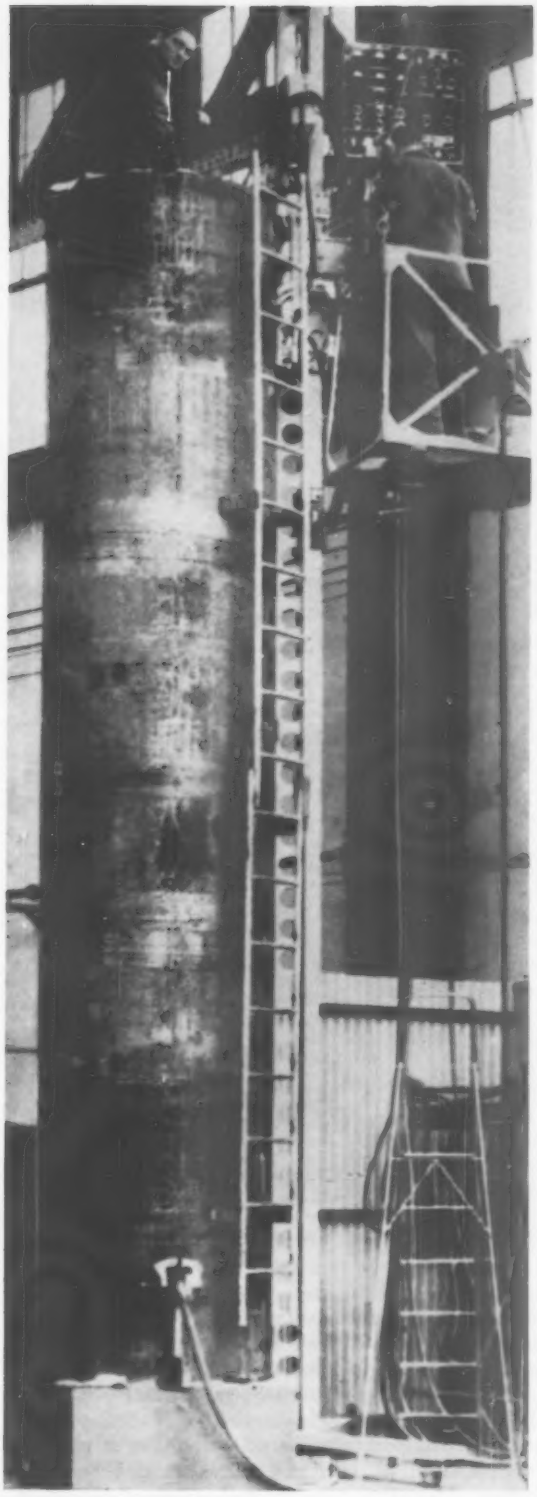


Fig. 1—Electroslag welding of longitudinal seams of a propeller stern-shaft tube in a shipyard in France (Chantier Naval de l'Atlantique)

Electroslag Welding—

A New Process for Heavy Fabrication

offers large savings through judicious application in the metalworking industry

BY R. DAVID THOMAS, JR.

What Is Electroslag Welding?

The term "electroslag" means an electric current-carrying slag. The slag is a conductive path for the electric current. When applied to welding, the term designates a process of electric welding wherein the heat necessary for fusing the filler metal and both sides of the joint is developed in the slag which covers the molten metal. The molten slag offers a resistance to the flow of electric current, and the heat thereby generated creates a melt having a temperature great enough to cause fusion of the metal.

The distinction between electroslag and submerged arc as media for welding will serve to clarify the fundamentals of the process. The latter is specifically what the name implies, an arc submerged under powdered granular flux. The depth of the flux and slag is, in practice, not sufficient to permit slag conductivity—the electric current might be said to short circuit the slag gap and thus cause an arc; the voltage of such an electric path is generally between 25 and 32 v. If in submerged-arc welding, as it is traditionally accomplished, it were possible to arrange a dam to permit the accumulation of molten slag to form a 1 to $1^1/_2$-in. depth, the arc would disappear, the voltage would rise to 45 to 55 v, and the current would be carried by the conductive slag. This is truly submerged-*melt* welding, where the melt or slag is the heating medium, rather than

R. DAVID THOMAS, JR. is President of Arcos Corp. Philadelphia, Pa.

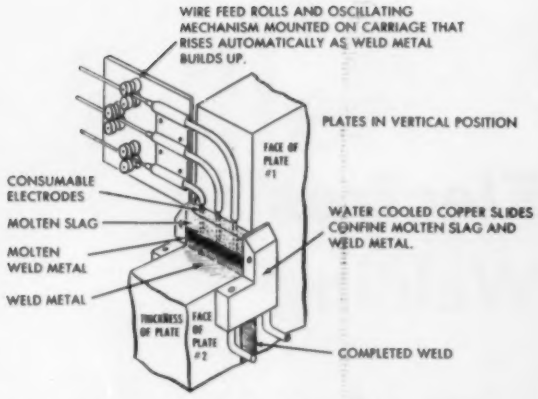

WIRE FEED ROLLS AND OSCILLATING MECHANISM MOUNTED ON CARRIAGE THAT RISES AUTOMATICALLY AS WELD METAL BUILDS UP.
PLATES IN VERTICAL POSITION
FACE OF PLATE #1
CONSUMABLE ELECTRODES
MOLTEN SLAG
MOLTEN WELD METAL
WELD METAL
WATER COOLED COPPER SLIDES CONFINE MOLTEN SLAG AND WELD METAL.
THICKNESS OF PLATE
FACE OF PLATE #2
COMPLETED WELD

Fig. 2—Diagrammatic sketch of the electroslag process

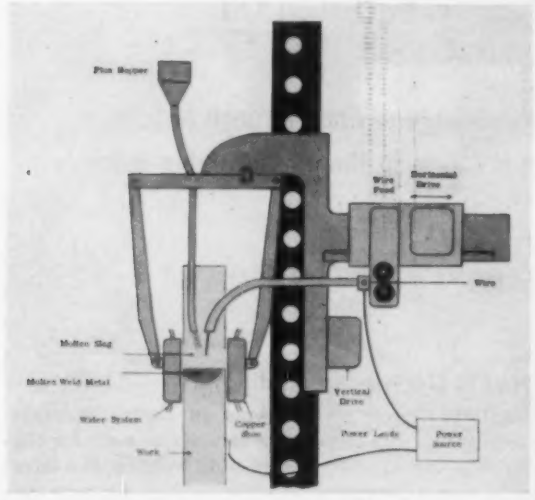


Fig. 3—Diagrammatic sketch of electroslag equipment and working relationships

the arc. Keeping in mind that electric power is the product of the volts and the amperes, slag welding, which permits $1^1/_2$ to 2 times the voltage, can produce a proportionally greater heat for the same current.

History

To provide a deep slag cover, scientists returned to an old idea of welding in the vertical position. The first patent describing a suitable welding scheme was granted to a Russian engineer by the name of Bernardos in 1908. In this patent he visualized a vertical welding process in which the two plates to be welded are placed upright and a graphite mold is provided on each side of the joint to retain the weld metal during welding.

Metallurgists have used slag conductivity as a means of fusing metals in a number of ways. Ingots have been cast from composite alloyed electrodes, using a thick slag and the conductivity of that slag

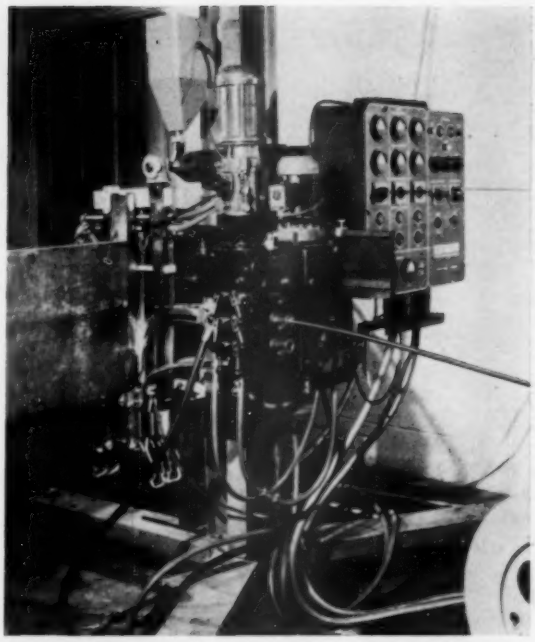


Fig. 4—Electroslag welding equipment with plate in position for welding

Fig. 5—Operating control panel

as a means of obtaining clean, uniform ingots. Hot tops for reducing shrinkage cavities in steel ingots have employed the electroslag heating means to control the final freezing of the ingot.

The combining of the vertical welding scheme of Bernardos with the slag-conductivity heating principle is attributed to another Russian engineer, G. S. Voloskevitch, at the Paton Institute of Welding in Kiev. According to published Russian literature, vertical welding by this process has been employed in Russia since 1951.

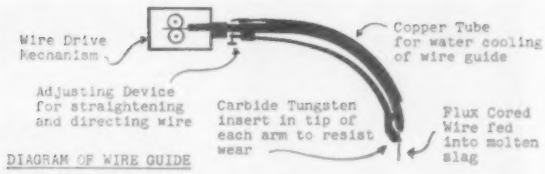

Wire Drive Mechanism
Copper Tube for water cooling of wire guide
Adjusting Device for straightening and directing wire
Carbide Tungsten insert in tip of each arm to resist wear
Flux Cored Wire fed into molten slag
DIAGRAM OF WIRE GUIDE

Fig. 6—Water-cooled wire guide

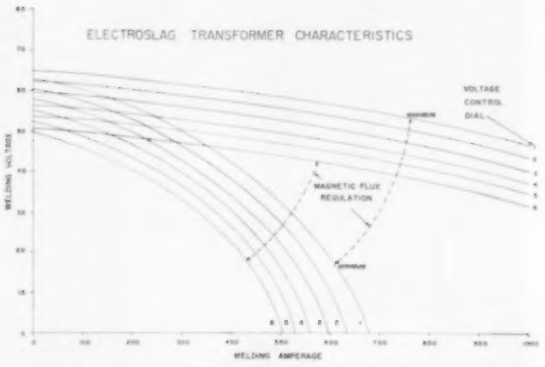


Fig. 7—Volt-ampere characteristics of electroslag welding transformer

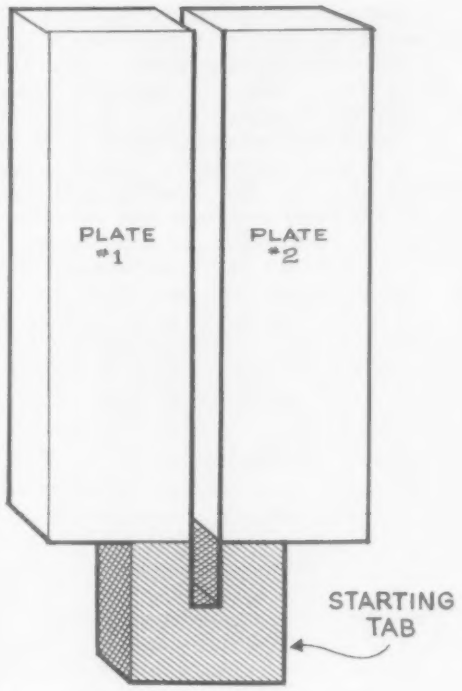


Fig. 8—U-shaped starting tab tack welded to bottom of joint

The advances made since that date have been primarily in the instrumentation of the process. The machines pictured in this article were all constructed in Belgium, whose engineers employed the designs and experience developed at the Bratislava Institute of Welding in Czechoslovakia.

Reports from behind the "Iron Curtain" indicated that the process could not be expected to give weld metal of the high mechanical properties expected from the traditional welding processes, especially in the notch-impact properties. The Belgian metallurgists made a substantial contribution to the production of high-quality welds by introducing composite wires with carefully-formulated fluxes and deoxidizers.

Operation of the Process

The process is applicable primarily for plates at least $1^1/_2$ in. in thickness. For plates up to 4 in. thick, one electrode is used; from 4 up to 10 in., two electrodes; and over 10 in., three electrodes. Figure 2 shows the copper molds, the molten weld metal, and the molten slag being fed by three current-carrying consumable electrodes.

Figure 3 shows the essential features of the electroslag machine. The vertical-drive motor carries the entire machine up a rack attached to the column. Wire is fed through a guide tube by wire-drive rolls mounted on a carriage which can oscillate within preset limits, depending on the thickness of the plate. When multiple electrodes are fed into the molten pool, each wire is connected to its own power transformer.

An over-all view of the machine is shown in Fig. 4. The operator's control panel, designed for either manual or automatic operation, is shown in Fig. 5. These controls actuate simple relays mounted in a separate relay cabinet.

Each wire is fed from reels through a water-cooled wire guide shown in Fig. 6. The tip of the wire guide is fitted with tungsten-carbide nibs which press against the wire for straightening purposes. The amount of pressure can be varied by a thumb screw located at a point accessible during the welding operation.

The transformers are 1000-amp rated capacity for 100% duty cycle. Each one has a built-in motor for changing the volt-ampere characteristics by the buttons marked "current control" on the operator's panel. The voltage is similarly controlled by the operator using the six-position selector switches. The range of choices at the operator's command is diagrammatically illustrated in Fig. 7.

The welding is begun in a U-shaped starting tab tack-welded to the bottom of the joint, as shown in Fig. 8. Starting is similar to submerged-arc welding, with the transformer set to provide drooping-voltage characteristics during the arc melting of the slag. Granular flux is added until the molten slag depth is about 2 in. As the amount of molten slag increases, the voltage is raised to the desired level and the leakage of the magnetic flux in the transformer is reduced to give nearly constant-potential operation. The current is finally adjusted to the desired level by varying the speed of the wire-feed drive.

The success of electroslag welding lies in proper operation of the automatic rising motion of the carriage. The molds, or shoes, shown in Fig. 9, carry a sensing element which automatically signals the rising motion. This water-cooled element, placed in the lower half of the mold, employs a 50-v relay circuit to energize the motor for raising the carriage whenever the slag film touching that element becomes sufficiently cool to become nonconductive. The carriage continues to rise until the slag again becomes conductive. This action occurs only when the traverse motion is at one of its extremities where it dwells for a few seconds before reversing direction.

The probe in the upper half of the mold is connected to a solenoid which introduces flux from the hopper as needed to maintain a constant slag depth.

Economics of the Process

For relatively heavy plates, electroslag welding offers economies over submerged-arc welding in two important regards:

1. The electroslag process is completely continuous (100% operating time), whereas the duty cycle in the multipass submerged-arc process usually varies from 35 to 65% operating time. The speed of welding will thus be $1^1/_2$ to 3 times faster due to this fact alone.

2. The deposition rate is 35 to 45 lb of weld metal per hour *per electrode*. In very heavy plates, using three electrodes, this means 105 to 135 lb/hr of weld metal deposited.

Using a joint spacing of $1^1/_8$ in., the rate of welding is shown in Fig. 10. Heavy plates ranging from 3 to 12 in. in thickness are completely welded at a speed of between 2 and 4 ft/hr.

Secondary savings are possible in materials, especially for heavy-plate welding. Submerged-arc welds in heavy sections must provide joint gaps sufficiently wide to permit slag cleaning of each pass. For plate thickness of 6 to 12 in., therefore, it is indicated that the electroslag process requires only one-half to one-third the amount of filler metal needed for submerged arc.

Another saving in materials results from the fact that the flux required for electroslag usually averages around 5 lb/100 lb of weld metal as compared with 100 to 125 lb of flux for submerged-arc welding. This amount will vary with the plate thickness, since the flux which is fused and therefore "used up" in electroslag welding is merely a thin film on each outer face of the weld and in the accumulated slag depth at the finish of a weld.

Flux cost per pound, because the fluxes are specially developed for the process, is somewhat higher than for submerged-arc welding. If composite wires are used instead of bare wire and a separate flux, the cost of materials is somewhat greater. In most applications, however, the amount of these materials is less, so that the cost per foot, even with higher material costs, is lower than for submerged-arc welding. In any case, the material costs are relatively small and become insignificant when considered in relation to the tremendous savings in labor costs.

Where fabrication shops are already equipped with submerged-arc welding equipment, no economical advantage is likely to exist in welding materials less than $1^1/_2$ in. thick. For thickness of 2 in. and above, there will be substantial benefits in using the electroslag process provided the work can be positioned for

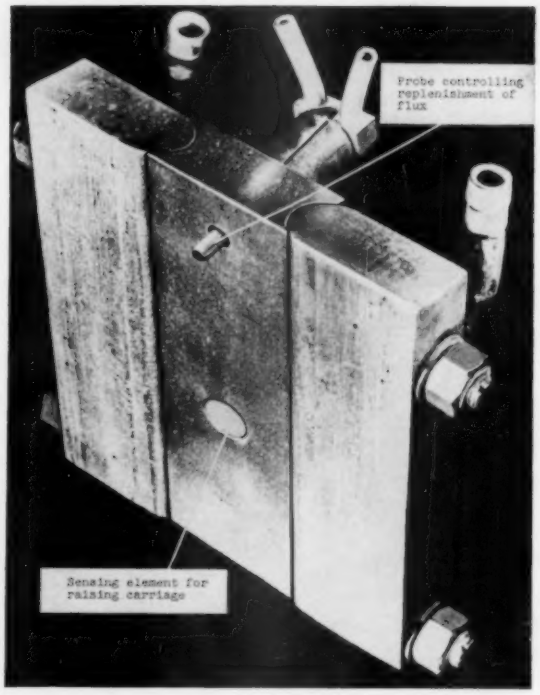


Fig. 9—Water-cooled shoes showing: (a) sensing element for raising carriage, (b) probe controlling replenishment of flux

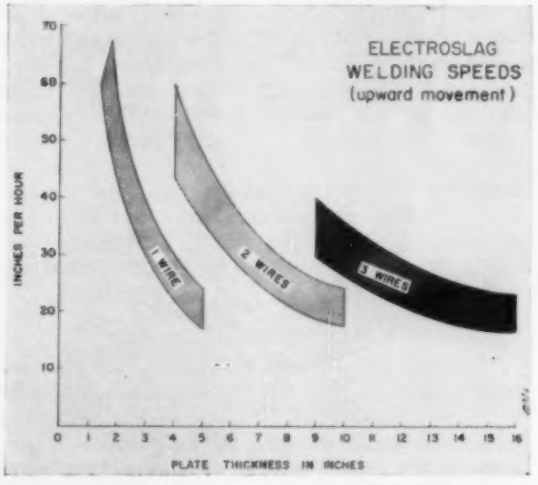
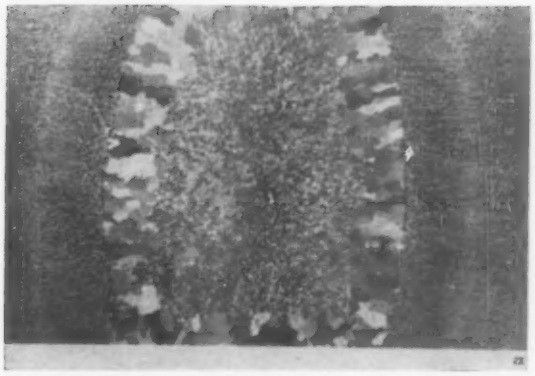
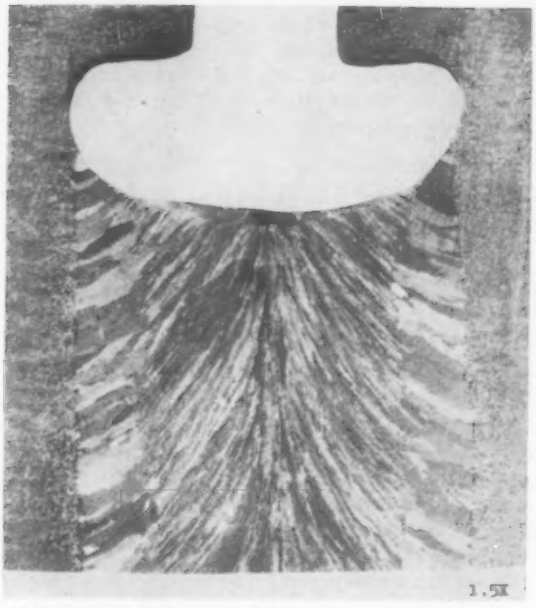


Fig. 10—Welding-speed rates for plate thicknesses up to 16 in., using 1, 2 and 3 wire operation



(a) Cross section. × ²/₃ (after reproduction)



(b) Longitudinal section. × ²/₃ (after reproduction)

Fig. 11—Macrographs of an electroslag weld, using a manganese-molybdenum high-tensile steel electrode

vertical welding. This is especially true, if one can thereby avoid the cost of complex manipulating equipment which is frequently necessary in sub-

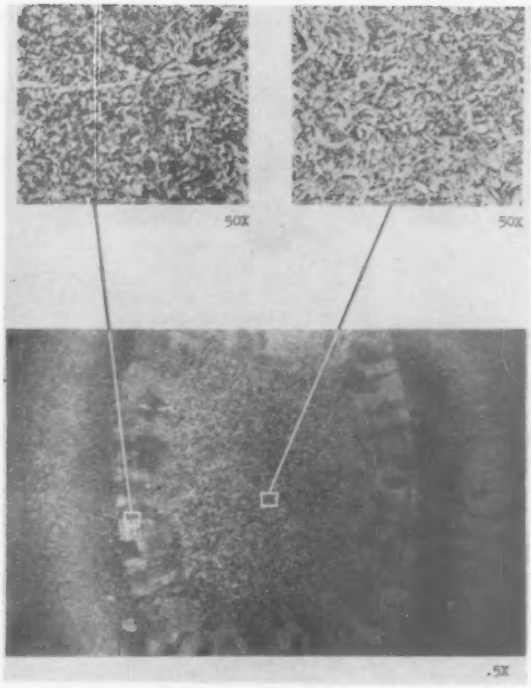


Fig. 12—Macrograph and micrographs of a mild-steel electroslag weld. (Reduced by ¹/₃ upon reproduction)

merged-arc welding.

Another possible economic use of electroslag welding is in the erection of heavy plates in the field. The equipment is simple and rugged and can be easily set up at a job site, permitting the vertical welding of thick plates at a very much lower cost than hand welding.

Metallurgy

Macrographs of typical sections of electroslag welds are shown in Fig. 11. These sections are from a manganese-molybdenum weld in a 3-in. thick medium-carbon steel plate and show the typical coarse dendritic pattern which has so frequently been reported in the foreign literature. Figure 12 shows a fine-grained cross section from a 3-in. mild-steel weld, using the special composite wire. The microstructure of this mild-steel weld indicates a

Table 1—Properties of Electroslag Welds

	Chemical analysis, %					
	C	Mn	Si	S	P	Mo
Manganese-molybdenum	0.08	1.84	0.37	0.016	0.019	0.32
Mild steel	0.13	1.13	0.33	0.024	0.020	0.09

	Mechanical properties				
	Yield strength, ksi	Tensile strength, ksi	Elongation in 2 in., %	Reduction in area, %	V-notch Charpy at room temp., ft-lb
Manganese-molybdenum	66.0	87.6	19	43	26, 28, 28
Mild steel	48.7	74.1	28	59	

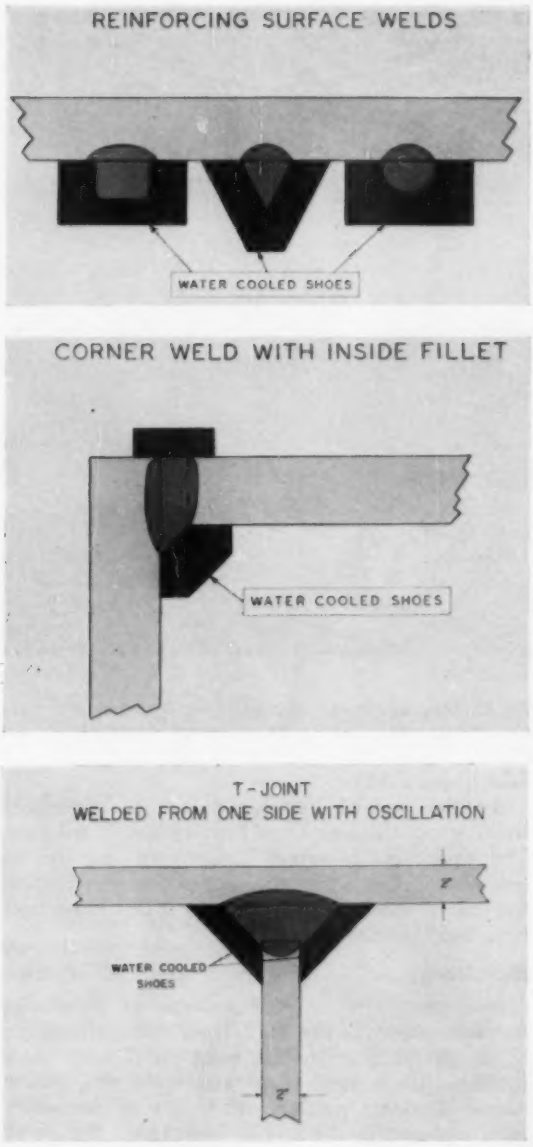


Fig. 13—Methods of using the electroslag process, other than for simple butt welds

very clean and uniform ferrite-pearlite pattern. The chemical composition and mechanical properties of these two welds were found to be quite satisfactory (see Table 1).

Our present knowledge of weld-metal metallurgy permits us to speculate on the suitability of the process for materials other than ordinary steel. Successful applications in heavy stainless steel and in low-alloy steels have already been reported in Europe. In quenched and tempered steels, some loss might be expected in notch-impact properties in the heat-affected zones due to the slow heating and cooling-cycles characteristic of the process. For the hardenable chromium-molybdenum steels and for the 3% nickel steels, this slow heating and cooling will be advantageous, making preheat unnecessary. In these low-alloy steels, the typical subcritical stress-relieving may be all that is necessary to produce the desired metallurgical properties, but some of the foreign literature indicates that a full normalizing followed by a stress-relief heat treatment is required. It appears that the process can be applied to nonferrous metals and alloys and to cast iron.

One important advantage claimed by the electroslag process is the very limited distortion due to weld shrinkage after cooling. There is no tendency, whatsoever, for the plates to bend at the joint, because of the single-pass principle, and shrinkage in the plane of the butt-welded plates is limited to about $^1/_4$ in., when the proper technique is used. The cooling pattern of the weld results in solidification of the outer surfaces, first, and the inside, last. This puts the outer surfaces under compressive residual stresses, rather than tensile stresses usually found on the surface of welds.

Applications

The butt welding of long seams in heavy plate is the simplest use of the electroslag process. By providing water-cooled molds of different shapes and contours, welds other than simple butt welds can be visualized, such as those shown in Fig. 13.

The process appears to lend itself well to the construction of heavy-walled cylindrical vessels. The longitudinal welds are no more difficult than simple butt welds in flat plates. Figure 1 shows an industrial use of the machine making the longitudinal seams of a propeller stern-shaft tube for a new 73,000-ton tanker. This structure, measuring $17^1/_2$ ft long, 42 in. in outside diameter, and $3^3/_4$ in. in wall thickness, comprised two formed half-cylinders joined by two electroslag welds.

The girth seams present a somewhat greater prob-

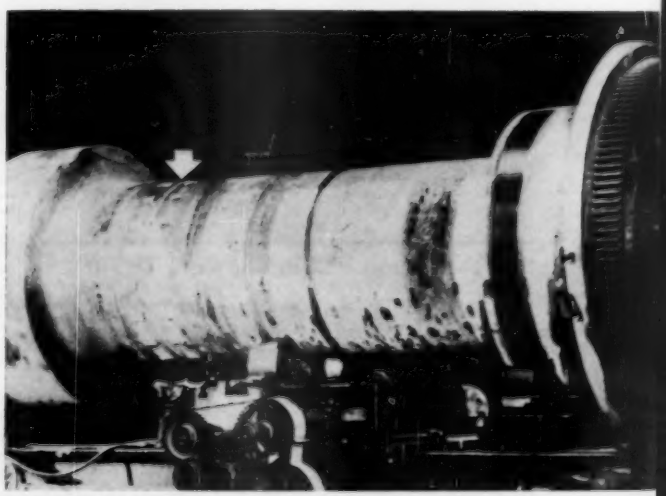


Fig. 14—Electroslag welding of girth seams in Czechoslovakia

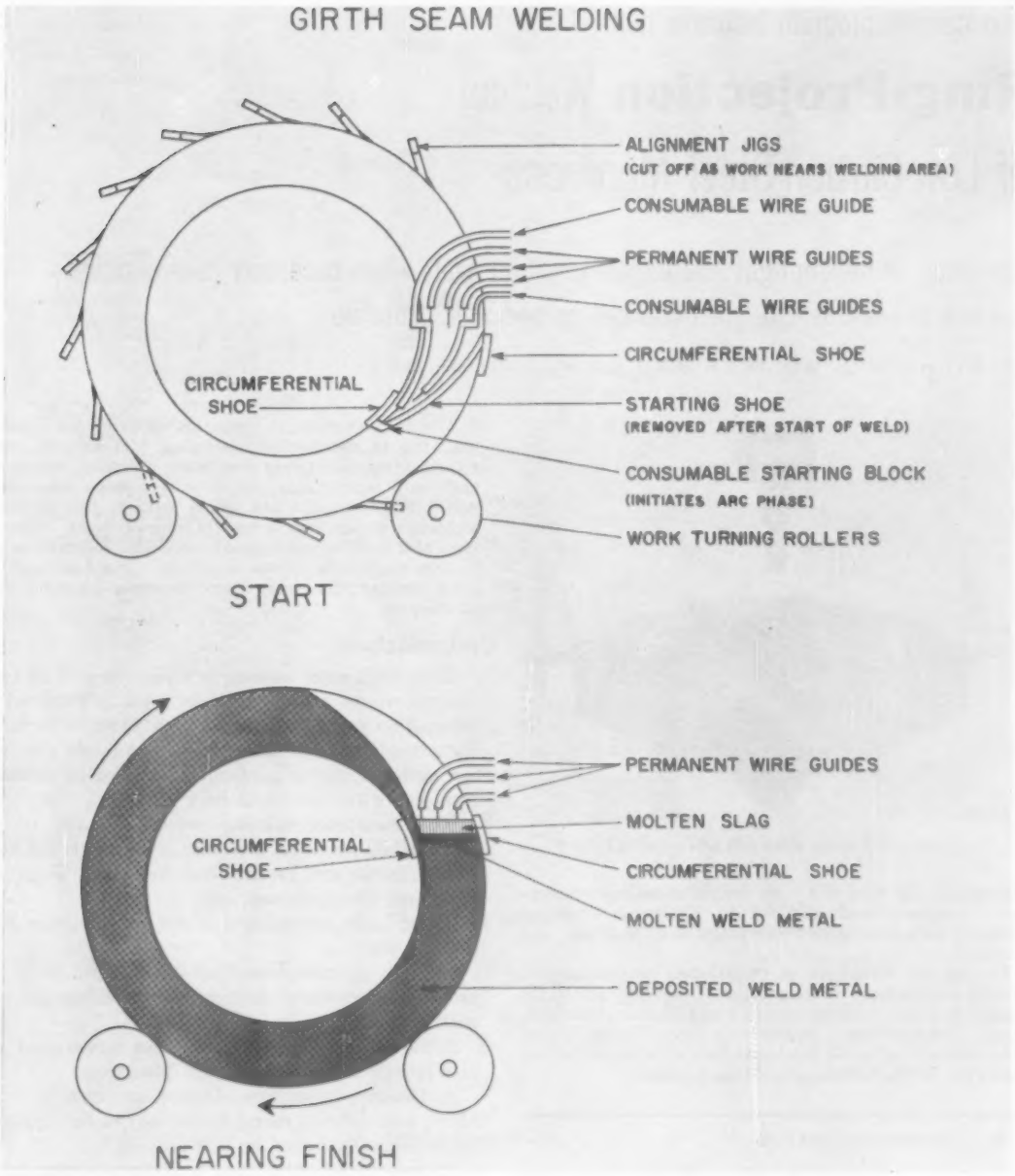


Fig. 15—Method of electroslag welding of a girth seam

lem for electroslag welding, although it is frequently used in Europe in the manner shown in Fig. 14. The setup for making such welds is illustrated in Fig. 15. The carriage of the machine is placed at a fixed level, and the sensing element circuit, instead of raising the carriage, operates the turning rolls to rotate the cylinder. Welding can be performed entirely by the electroslag machine, from start to finish.

The first industrial machine of this type to be set up in this country has been operating since about the middle of August 1959. The evaluation of welds made with different filler metals and fluxes is going forward and is being supplemented by work in laboratories of potential users of the process. Data on various materials are being collected to satisfy the requirements of insuring and other code-inspection groups.

If the countries of Europe, on both sides of the "Iron Curtain," having a much less incentive to save man hours, can justify its use, how much more will the process offer large savings to fabricators in this country! The largest steel-producing country in the world has much to gain by the judicious application of the electroslag welding process.

Development program indicates that

Ring-Projection Welding of Low-Carbon Steel Munitions

can result in helium-tight and impact-resistant seals when necessary consideration is given to joint design, electrode design and weld schedule

BY MICHAEL J. WELTHER AND SALVATORE M. ROBELOTTO

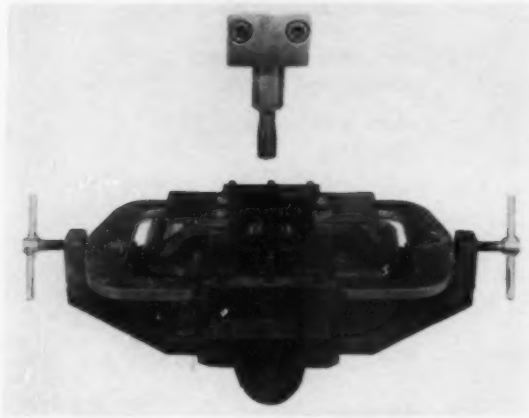


Fig. 1—Combination lower electrode and welding fixture

ABSTRACT. As part of a toxic-munition sealing-development program conducted for U. S. Army Chemical Corps., toxic-munitions ring-projection welding was studied.

During this investigation, twenty-two projection-weld closure designs were developed and thoroughly tested for helium leakage, pushout strength and impact resistance. Four (100-specimen) consistency runs, made under production conditions, produced data substantiating the reliability of the resistance-welding process.

The highest-strength munition closure was produced with the 45 deg double-bevel plug. This configuration required comparatively low weld pressure, weld-phase shift and weld time. As relatively large amounts of metal forge-out did not cause leaking, the developed welding schedule was proved to be not critical. This cap may also be reversed in production and requires no projection machining on the munition. Weld settings and joint configurations were also determined for other types of closures.

Table 1—Welding-machine Data

	Press-type machines, three-phase			
	2STK[a]	2ST	5STK[a]	7ST
Pressure—at 80 psi line pressure, max lb	4,300	4,300	18,500	38,000
Max short-circuit secondary current, amp	70,000	70,000	220,000	312,000
Welding stroke, in.	1/2	1/2	1	1 1/2
Retraction stroke, in.	3 1/2	3 1/2	4 1/4	6
Kva	100	100	400	600

[a] Dekatron control.

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Introduction

Ring-projection welding is a process used in applications where a pressure-tight joint is required between two parts, and for joints subject to torsional-shear loads such as those applied to studs and nuts. A ring projection is normally machined or embossed into one of the details to be joined.

This resistance-welding process is used to join such metals as: iron, low- and medium-carbon steel, Monel, brass and bronze, stainless steel, zirconium, clad steel, molybdenum, etc.

Three basic advantages of the projection-welding process are:

1. High production—Automatic equipment can produce in excess of 800 projection welds per hour with a single weld station.

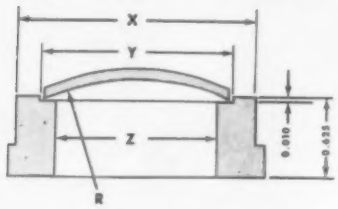
2. Low heat input—Assemblies have good surface appearance and minimum distortion.

3. Design versatility—Dissimilar metals which alloy, and difficult metal-thickness combinations can be structurally joined by this process.

It was determined that a large advance in the economical manufacture of chemical munitions could result if a ring-projection weld closure were developed. Prior to this investigation, press fits were used. Parts rejection and machining costs due to the dimensional tolerance required on both the closure and munitions added considerably to over-all munition and inspection cost. Mechanical seals also had questionable leak tightness under varying climatic, handling and storage conditions.

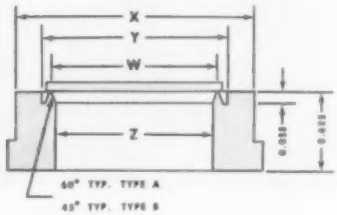
Ring-projection welding was investigated because the process required less than one percent of the total heat of either a brazing or fusion-welding process. This reduction in heat input eliminated volatilization of the munition charge, parts distortion and

Table 2—Munitions and Plug Design for Ring-projection Welding[a]



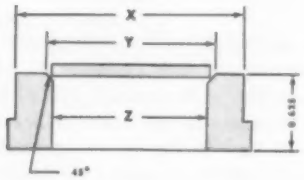
1. Welch plug, a, b, c, d

Code	Dimension X	Y	Z	Radius R	Plug thickness	Plug diam
a	0.950	0.890	0.750	1.100	0.083	0.875
b	1.500	0.890	0.750	1.100	0.083	0.875
c	1.500	1.385	1.250	2.000	0.083	1.375
d	2.000	1.385	1.250	2.000	0.083	1.375



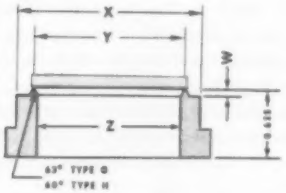
2. Flat disk, a, b

Code	Dimension W	X	Y	Z	Disk thickness	Disk diam
a	0.874	1.5	1.04	0.750	0.093	0.998
b	1.314	2.0	1.4	1.250	0.093	1.377



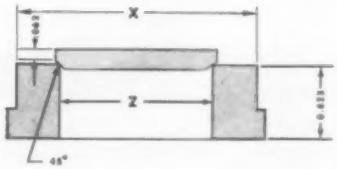
2. Flat disk c, d, e, f

Code	Dimension X	Y	Z	Disk thickness	Disk diam
c	0.950	0.875	0.75	0.093	0.844
d	1.500	0.875	0.75	0.093	0.844
e	1.500	1.375	1.25	0.093	1.346
f	2.000	1.375	1.25	0.093	1.346



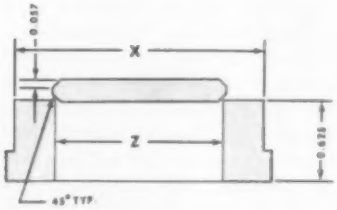
2. Flat disk g, h

Code	Dimension W	X	Y	Z	Disk thickness	Disk diam
g	0.100	0.950	0.850	0.750	0.093	0.998
h	0.055	1.500	1.314	1.250	0.093	1.377



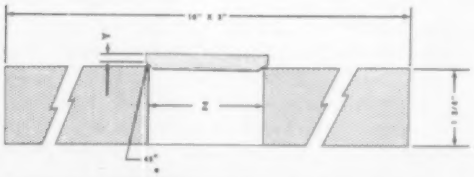
3. Single-bevel disk a, b, c, d

Code	Dimension X	Z	Disk thickness	Disk diam
a	0.950	0.750	0.125	0.845
b	1.500	0.750	0.125	0.845
c	1.500	1.250	0.125	1.345
d	2.00	1.250	0.125	1.345



4. Double-bevel disk a, b, c, d

Code	Dimension X	Z	Disk thickness	Disk diam
a	0.950	0.750	0.160	0.845
b	1.500	0.750	0.160	0.845
c	1.500	1.250	0.160	1.345
d	2.00	1.250	0.160	1.345



5. Single-bevel disk a, b

Code	Dimension Z	Disk thickness	Disk diam	Disk flat Y
a	1.000	0.250	1.242	0.062
b	1.250	0.312	1.450	0.125

[a] Note: All dimensions in inches.

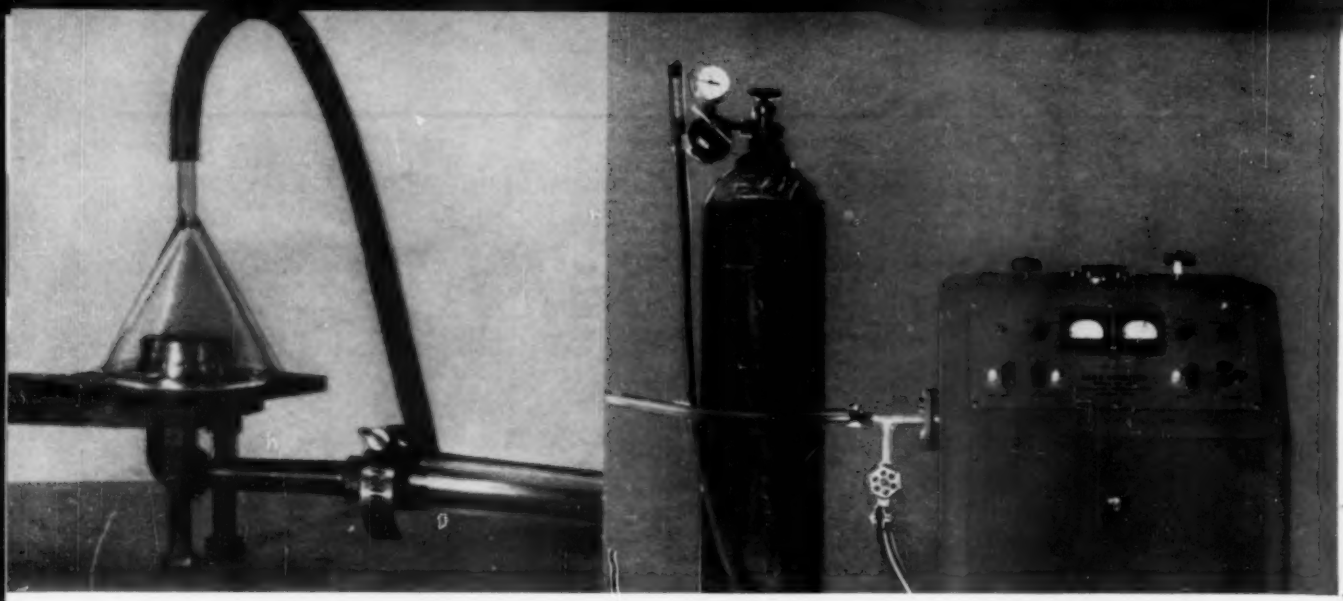


Fig. 2—Helium leak-test setup

other hazards. Typical sealing requirements of a munition closure is that passage of helium under pressure through the joint be less than 1×10^{-6} cc/sec in a minimum of consecutive closures.

Objective

The objective of this program was to develop a ring-projection welding process resulting in a shock-resistant, metallurgically sound, leak-tight, high-strength, consistently reproducible munitions closure. This consisted of the following:

1. Develop closure designs and related weld schedules which consistently produce good-physical-strength seals that do not leak helium in excess of 1×10^{-6} cc/sec at a differential pressure of one atmosphere.

2. Determine reliability of final joint design and related weld schedule by 100 assembly consistency-weld runs.

3. Determine welding-machine characteristics and AISI materials limitations to the developed process.

Materials and Specimens

Data for this report were obtained from simulated munition specimens made of AISI C-1010 and AISI C-1020 low-carbon steel. Chemical analysis revealed standard percentages of alloying and impurity materials.

Simulated munitions bodies had four general projection configurations with either a 0.750 or 1.250-in. diam hole. Four closure caps were fully developed with both their respective thin- and heavy-wall munition body. The flat disk, welch plug and the double- and single-bevel caps with the respective thin- and heavy-wall munition projection configuration are shown in Table 2.

Equipment

1. Welding Equipment—This study was conducted using three-phase press-type spot-welding machines. The machines, Table 1, had electronic-counter control of weld time, cool time, current decay, preheat, postheat, quench, variable pressure and advanced recompression.

2. Electrodes—Upper electrodes were RWMA Class III. Lower electrode was manufactured to promote uniform current flow to the munition weld zone. Munitions contact areas of lower electrode fixture were made of RWMA, Class IV copper alloy. The final welding fixture used in this program is as illustrated in Fig. 1. Ring-electrode inserts and stainless-steel locating holders enabled the fixture to adapt to processing of each simulated munitions configuration. Specimen-holding pressure was applied by two sets of clamps and attendant hand screws. A production-welding fixture would employ pneumatic clamping to improve production time.

It is to be noted that the closure seals the munition. Therefore it is impossible to have the welding electrodes in opposition to one another. Thus, the fixture was designed to clamp tightly around the periphery of the munitions for uniform current conduction in the contact area.

3. Recording Equipment—Recording weld analyzer with dual-channel direct-writing oscillograph, universal amplifier and modified d-c amplifier were connected to the welding machine. Operationally, the equipment monitored current wave shape and timing. Through a pickup coil and electronic integrator, the intelligence was introduced to the recording oscillograph. In addition, a record was made of mechanical electrode force as indicated by a deflection rod and strain-gage bridge. By this collation of the electrode force, wave shape and timing, welding-machine functions could be readily ascertained. This control could be adapted to automatic production equipment to monitor its performance. The device used to measure secondary current is comprised of a toroid coil, integrated network, amplifiers and two meters. One meter is a thermocouple-type rms and the other is of electrostatic nature which indicates peak current of the weld impulse of greatest magnitude during current flow. The secondary-

current measuring device used was developed for use on this project.

While neither the recorder and sustaining equipment nor the secondary-current measuring device are in themselves self-sufficient, coupling of the two units promise to be an excellent means of automatic-production quality control.

Testing

A comprehensive test procedure was followed to insure weld quality. Initially, all of the following tests were applied. However, sampling soon disclosed that development control could be exercised and weld quality specifically determined by applying only the leak and pushout tests. These tests were used exclusively during weld-schedule development. The final schedule was then qualified by being applied to the production of a number of assemblies which were thoroughly tested by the complete procedure that follows:

1. Leak—As the primary objective of the program was to produce a strong projection-welded seal prohibiting the passage of helium, the most important test—the leak test—was conducted in the following manner.

(A) Dye-penetrant test: Preliminary leak detection was performed with the aid of a dye-penetrant test. An amount of dye penetrant was placed at the weld root. If cracks, crevices or unwelded zones existed, the dye flowed to the face of the weld and became visually apparent. After this preliminary test indicated that a leak-tight weld had been developed, the dye-penetrant test was discontinued and replaced by the sensitive helium test.

(B) Helium: As shown in Fig. 2, the specimen was placed on a rubber gasket and manifold assembly in such manner that the specimen formed a closed chamber. The manifold was connected to an external roughing vacuum pump and helium-tuned mass spectrometer. Initial evacuation of the specimen chamber by the external roughing pump was further reduced to 0.1 micron (gage reading) by a diffusion pump within the leak detector. Confined helium gas was then introduced to the weld periphery by application of the vessel illustrated in Fig. 2. Welds which permitted helium to pass at a rate of 1×10^{-6} cc/sec or greater were considered leakers and rejected. The helium-leak test was performed before and after the drop test described below.

2. Drop Test—To determine whether welds were brittle or sustained deterrent internal weld stresses, simulated munitions were three-times dropped to a steel plate from a height of 12 ft. This test simulates drastic handling occurrences on munitions. After such maltreatment, specimens which again passed the helium leak test were considered free of excessive stress or embrittlement.

3. Pushout Test—Upon completion of leak and drop tests, specimen welds were subjected to a pushout test. As the simulated munitions were machined with a shoulder in the lower section, also used for lower electrode contact, the specimens were inserted into a steel sleeve in such a manner that the shoulder was restrained by the sleeve rim. A ram approximately 0.030-in. smaller than the specimen-hole diameter was then inserted into the specimen chamber. Force subsequently applied to the ram by a universal testing machine imposed a combination shear- and-peel load on the specimen closure. The only specimens considered satisfactory were those in which fracture occurred in the base metal (see Fig. 3).

4. Metallurgical Test—After developing a weld

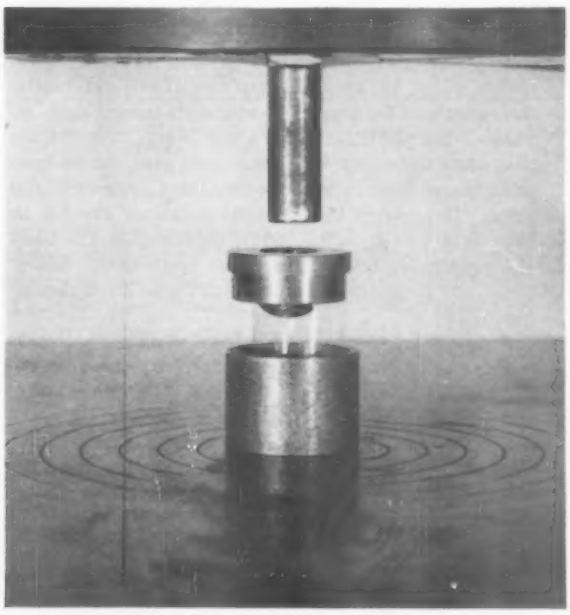


Fig. 3—Exploded view of pushout test and specimen after pushout testing

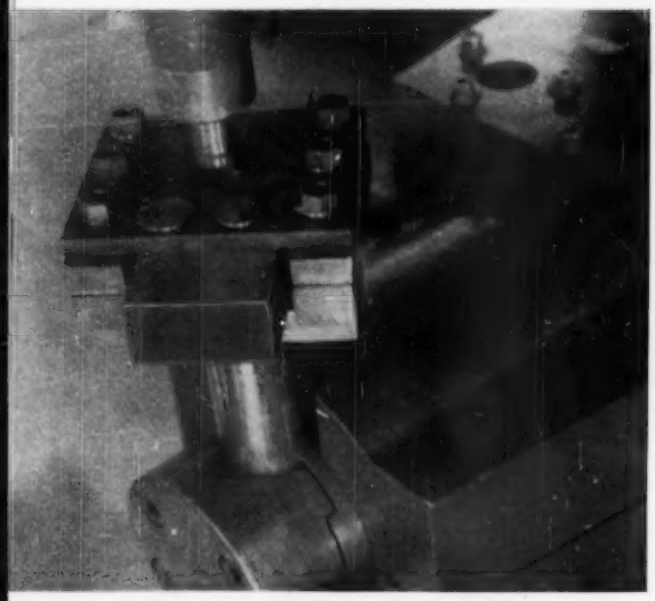


Fig. 4—Initial welding fixture used in the development of closure design 5 (Table 2)

Fig. 5—Continuity-test welding setup on resistance-welding machine. Recording instrumentation also shown

schedule meeting the previous test requirements, duplicate welds were prepared and sectioned for macro-and microexamination. Inspection was made to determine porosity, cracks, voids, discontinuities or interface and structural changes. Knoop-hardness tests were conducted to determine approximate strengths of the weld zone and hardness variations between base metal and weld zone. All welds were required to be metallurgically sound before a developed weld schedule was acceptable.

Discussion of Development

Preliminary development was performed using the fixture shown in Fig. 4. Initial welding schedules were made using the data from Reference 1. Original weld schedules were subsequently adjusted until produced welds met all the previously described tests. This fixture concentrated the current uniformly in the weld area. In conjunction with the upper electrode, it simulated actual munitions-welding conditions. Projection and plug designs evaluated in this fixture are shown in Table 2, Design Type 5. Plug-to-munitions weld schedules developed in the initial tooling-design tests, using the Fig. 4 fixture, are shown in Table 3.

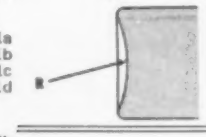
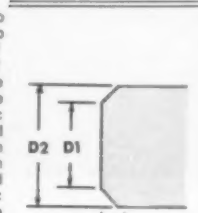
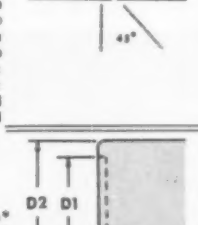
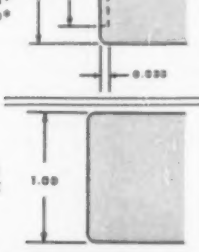
It is to be noted from this initial development work that the fixture was time-consuming to load and unload. Also, when the fixture hold-down screws were not uniformly tightened, electrode-contact force varied and allowed for unwelded areas. This magnified the need for good fixture design as well as joint design on ring-projection-welding application.

The remaining development work discussed here was performed using the fixture shown in Fig. 1. Although all closure configurations were successfully welded, using the Fig. 5 machine setup, the following design considerations require discussion:

1. While not critical, the following was found to be true. Closure diameters exceeding munitions body ID by $^{1}/_{16}$ in. or less caused the closure to burn too deeply into the munition body. Closure diameters in excess of $^{1}/_{8}$ in. greater than the ID of the bodies (heaviest wall thickness investigated) caused heat unbalance between the closure and body. As closure diameters increased, so did the weld area, which necessarily required greater weld force, current and time. It appears that closure diameter should be between 0.090 in. and 0.125 in. greater than the body ID, preferably toward the lesser dimension. Munitions and plug designs shown in Table 2 are recommended.

2. Initially, 45-deg double-bevel closure specimens satisfactorily welded with greater ease than did 45-deg single-bevel closure specimens. Examination of the pushout-fractured interface of specimens of each design disclosed the weld-contact area of the 45-deg double-bevel closure design to be much less than the weld-contact area of the 45 deg single-bevel closure design. It was found that the double-bevel-configuration permitted plastic deformation with the result that the contact area was not greatly increased during welding. In contrast, the single-bevel closure

Table 3—Final Weld Schedules; Welding-machine Schedules[a]

Specimen design	Upper electrode design	Electrode dimension, in.		Machine	Weld force, lb	Phase-shift weld, %	Phase-shift current decay, %	Heat cycles	Current-decay cycles	Cool cycles	Impulses	Transformer series or parallel	Pushout strength range, lb	No. specimens
1a		R = 1.1	Diam = 0.87	2STK	1000	55	10	5	1	0.5	3	P	4,000/6,300	137
1b		R = 1.1	Diam = 0.87	2STK	1200	65	10	5	1	1.5	5	P	4,300/5,300	65
1c		R = 2.0	Diam = 1.31	5STK	3100	78	30	6	1	1.5	6	S	7,300/15,800	100
1d		R = 2.0	Diam = 1.31	5STK	3100	70	10	6	1	1.5	6	S	9,000/12,800	142
2b		D_1 = 1.37	D_2 = 2.0	2STK	2800	90	20	6	1	1.5	6	P	9,200/10,900	12
2b		D_1 = 1.37	D_2 = 2.0	5STK	2550	80	..	4	..	1.5	4	S	7,300/19,100	100
2f		D_1 = 1.37	D_2 = 2.0	5STK	2750	85	..	4	..	1.5	4	S	10,500/12,700	29
2f		D_1 = 1.34	D_2 = 2.0	2STK	2800	98	20	6	1	1.5	6	P	4,600/10,200	16
2e		D_1 = 1.34	D_2 = 2.0	5STK	2750	75	30	6	1	2.5	4	S	9,100/15,800	100
2e		D_1 = 1.34	D_2 = 2.0	2STK	2800	90	20	6	1	1.5	6	P	8,000/9,800	16
2c		D_1 = 0.84	D_2 = 1.0	2ST	1400	84	20	5	1	1	7	P	8,000/8,400	20
2d		D_1 = 0.84	D_2 = 1.0	2STK	2100	80	20	4	1	1.5	4	P	7,200/8,600	27
2h		D_1 = 1.37	D_2 = 2.0	5STK	2550	88	..	5	..	1.5	4	S	12,800/19,300	26
2h		D_1 = 1.37	D_2 = 2.0	2STK	2800	90	20	6	1	1.5	6	P	9,000/12,400	12
3d		D_1 = 1.28	D_2 = 2.0	5STK	2550	90	..	3	..	0.5	8	S	15,000/22,000	178
3c		D_1 = 1.28	D_2 = 2.0	5STK	2550	24	..	3	..	1.5	8	P	11,100/17,000	11
3a		D_1 = 0.72	D_2 = 1.0	2ST	1200	95	40	5	4	1	2	P	14,000/17,300	37
3b		D_1 = 0.72	D_2 = 1.0	2STK	1500	85	30	5	1	1.5	5	P	8,000/11,200	77
4a		D_1 = 0.85	D_2 = 1.0	2ST	1500	84	20	5	1	1	7	P	20,900/24,000	20
4b		D_1 = 0.85	D_2 = 1.0	2STK	1500	75	10	5	1	2.5	5	P	15,000/25,000	24
4c		D_1 = 1.35	D_2 = 2.0	5STK	2750	75	30	6	1	2.5	4	S	13,100/36,000	100
4c		D_1 = 1.35	D_2 = 2.0	2STK	2000	90	30	5	1	1.5	8	P	25,500/27,500	15
4d		D_1 = 1.35	D_2 = 2.0	5STK	2300	38	..	4	..	1.5	4	P	19,100/25,100	27
4d		D_1 = 1.35	D_2 = 2.0	2STK	2200	95	30	7	1	1.5	8	P	22,000/24,500	18
5a*		D_1 = 0.88	D_2 = 1.31	7ST	5700	85	..	5	..	2	17	P	...	..
5b*		D_1 = 1.12	D_2 = 1.43	7ST	5700	85	..	10	..	2	28	P	...	..
2a				2STK	1700	85	45	5	1	1.5	7	P	6,000/12,000	28
2g				2ST	1500	92	45	5	1	1	7	P	19,000/23,000	19

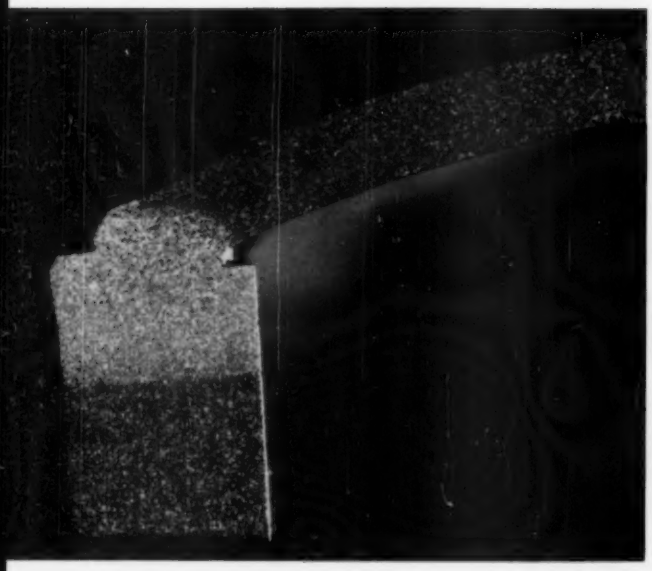
[a] Thirty-cycle quench time and 100-cycle postheat at 30% phase shift used to simulate a procedure for reducing the hardness of medium-carbon steel welds was added. This procedure is useful on medium-carbon steel and is not a requisite for low-carbon steel.
[a] Note all dimensions in inches.

form was so supported by the electrode that plastic deformation did not occur, and the resulting contact area was, therefore, greatly increased during welding. Thus, the greater contact area of this latter configuration so decreased current density that a good weld was not readily attained.

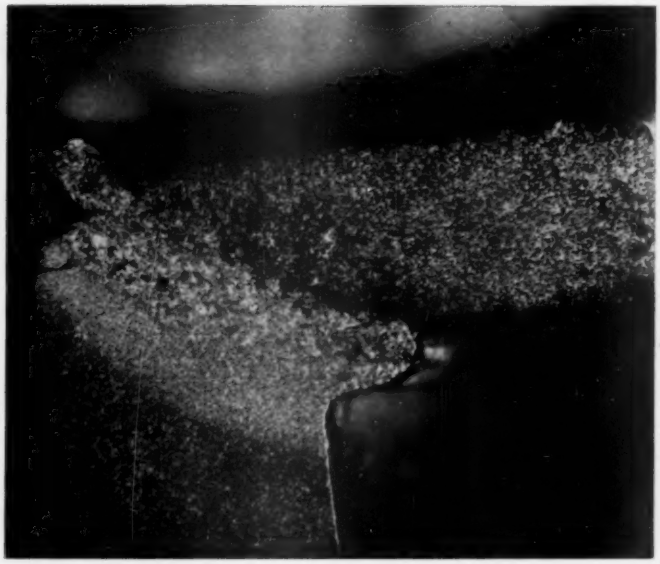
3. In an effort to increase the weldability of the single-bevel design configuration, an electrode of lesser dimension than the closure diameter was substituted. Such reduced electrode diameter permitted plastic deformation to occur in the plug and thereby reduced the tendency for contact-area growth. Although this electrode modification increased the weldability of the 45 deg single-bevel closure design, the ease of weldability attained did not equal that of the 45-deg double-bevel closure configuration.

4. The highest strength weldments were produced with the 45-deg double-bevel closure. This configuration required surprisingly low weld pressure, weld-phase shift and weld time. As relatively large amounts of expulsion did not cause leaking, the developed schedule was proved to be not critical. This cap may also be reversed during production assembly.

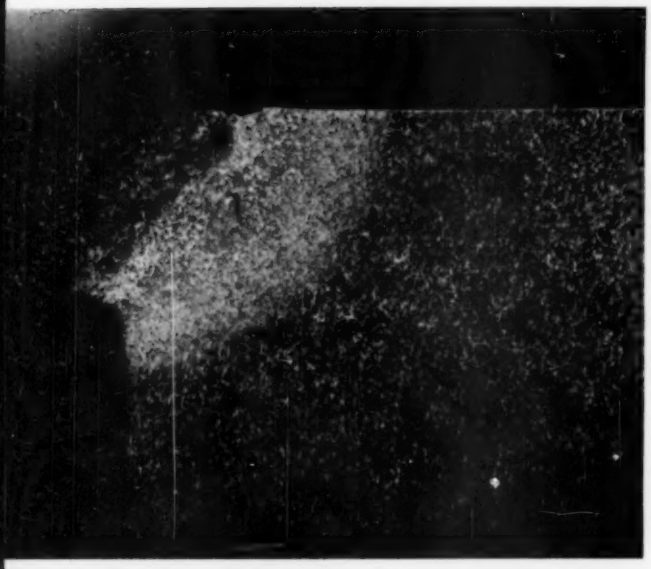
5. Welch-plug closure welding was found to be somewhat critical until due cognizance was given to proper assembly alignment, electrode configuration and dressing. The necessity of proper alignment was dictated by plug and electrode contour. If misalignment occurred, the electrode did not make



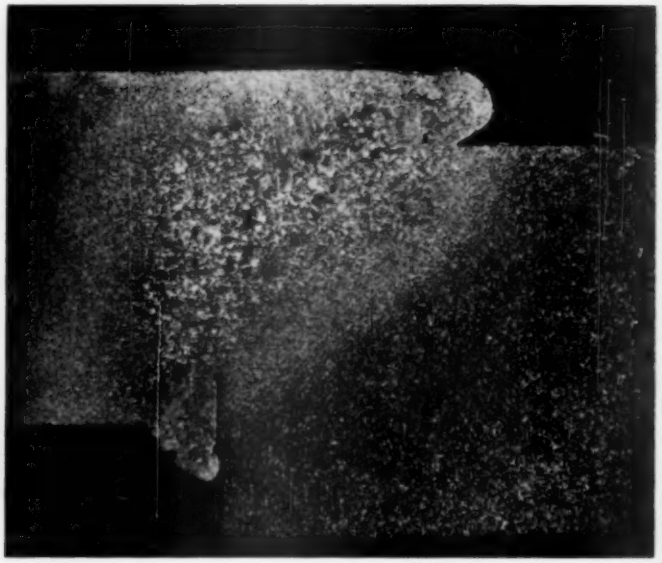
(1c)



(2b)



(2c)



(4c)

Fig. 6—Photomacrographs of typical continuity-test specimens. × 10

uniform contact on the surface of the plug and thereby caused "hot spots" in the weld periphery. Several instances were noted wherein a developed schedule would no longer produce satisfactory welds after electrodes had been machined or dressed. This was attributed to change in area contact between the

Table 4—Continuity-test Results

Specimen design	No. specimens pushed out	Range of pushout, lb	Average pushout, lb	Base-metal fracture	Weld-area fracture	Helium-leakage test
4c	88	13,100–36,000	22,400	88	0	No leaks
1c	87	7,300–15,800	12,850	83	4	No leaks
2c	88	9,100–15,800	13,400	86	2	No leaks
2b	84	7,300–19,100	11,100	84	0	No leaks

plug and electrode. Later development demonstrated that the use of undersized electrode diameter and increased weld pressure deformed the plug to the electrode contour. Thus, the use of an undersized electrode diameter somewhat reduced the critical requirements of electrode alignment and contouring. Schedules developed with the undersized electrode resulted in reliable, helium-leak-tight welds. The Welch-plug closure can be used successfully if care is exercised in machining electrode contour and in electrode-closure alignment.

6. The flat-disk closure readily welded to bodies with a 45-deg bevel and to bodies containing a sharp-cornered machined-ring projection. Although very little edge margin resulted in welds of the latter combination, no expulsion occurred and the welds were neat in appearance, of good strength and leak tight. The additional cost of properly machining these bodies is somewhat offset by the reversible feature of the economical flat closure which lends itself to automatic production assembly.

7. All closure designs were successfully welded. Helium-leak-tight seals and relatively high pushout strengths were attained. Fractures occurred in base metal. Table 3 is a summary of welding machines used, pushout-strength range, number of specimens and weld schedules used.

A large number of specimens were sectioned and examined both macroscopically and microscopically. Figure 6 shows photomacrographs of typical specimens examined. The structures are typical of plain low-carbon steel and contain varying amounts of pearlite and ferrite in proportion to the carbon content peculiar to the particular steel. Microexamination at × 100 showed a satisfactory weld structure with no porosity, cracks or discontinuities evident. Weld-zone Knoop-hardness traverses converted to Rockwell hardness indicated the weld zone of all specimens was within the range Rockwell C20-C36.

Production-consistency Run

Upon completion of the weld schedule and munitions-design development program, four closure designs were selected for a production-consistency run. One hundred of each of the closures were welded under production conditions. The selected closure designs were 1c, 2b, 2c and 4c, Table 2.

Instrumentation consisted of the previously discussed recorder (recording electrode force, weld timing and current-wave shape) and current-measuring device. As production-consistency run welding times were so short, the electrostatic meter was used rather than the thermocouple (rms) meter (see Fig. 5 for welding setup).

Each weldment was helium-leak tested, drop tested, again helium-leak tested, then either sectioned for metallographic inspection or subjected to pushout test. There were absolutely no leaks detected in any of the 400 consecutive closure welds either before or after drop testing. All except six fractures occurred in base metal. Table 4 presents a summary of 400 welds.

Selection of Welding Machine

Three welding machines were used in the final development program, PMCO 2ST, PMCO 2STK and PMCO 5STK. The only difference between the PMCO 2ST and PMCO 2STK machines is the type of controls. Information such as heat cycles, impulses, weld pressure, etc., were directly transferable from one machine to the other. Only adjustments to weld phase-shift control were necessary in duplicating welds on either machine. Most of the development was conducted with the PMCO 2STK.

The only closure design which was not welded on the smaller machines was the 3c and 3d, Table 2, munition body with the 45-deg single-bevel closure cap. Althouth all the closure designs could be welded on the smaller machines, the munitions bodies containing a hole diameter of $1^1/_4$ in. required long welding time at almost full current capacity of the machines. Such practice is to be discouraged, as use of a welding machine at maximum-current output allows no reserve for possible adjustment of settings. Also, by use of the larger machine, higher production rates were attained. To illustrate, by substituting a PMCO 5STK for the PMCO 2STK machine, welding time was reduced by approximately one-half. Results indicate a 200 kva machine would be optimum for welding of munitions.

Conclusions

1. Twenty-two closure designs, Table 3, and related weld schedules, Table 4, were developed and did not leak helium in excess of 1×10^{-6} cc/sec at a differential pressure of one atmosphere.

2. High pushout strength, metallurgically sound, porosity-free and ductile ring-projection welds can be developed in AISI C-1010 and C-1020.

3. Four consistency-weld runs of 100 specimens each, run under production conditions, demonstrated the leak tightness and strength reliability of the closure designs.

4. A 200 kva resistance-welding machine of the type in Table 1 with automatic feed is optimum for ring-projection welding closures of 0.75 to 1.25-in. diam munitions holes.

Acknowledgment

Acknowledgment is due to John D. White, project engineer, and other personnel of the Chemical Corps, Chemical Warfare Laboratories, Army Chemical Center, Edgewood, Md., for their interest and direction on this project. The authors also wish to acknowledge the valuable discussions and suggestions made by Henry E. Guerin and Charles A. Carlson under whose supervision this work was conducted in the Sciaky Bros., Inc. Western Research Division.

References

1. "Massey-Harris Ferguson Company Limited—Tentative Design Standards for Resistance Formed Welds in Mild Steel." Copies available on request, Sciaky Bros., Inc., December 1956.

2. Farrell, W. J., and Solomon, J. L., "Resistance Welding Machines, New Concept for Control of," THE WELDING JOURNAL **36** (4), 356-362 (1957).

3. Hess, W. F., and Childs, W. J., "A Study of Projection Welding," *Ibid.*, **27** (12), Research Suppl., 712-s to 732-s (1947).

Operator shown feeding an automated line of welding presses, to weld the inner and outer center-pillar panels together

Increased safety, higher product quality, greater operating convenience and lower production costs are among the many advantages attributed to

Automatic Welding Procedures for **Sheet-Metal Stampings**

BY H. A. FRANKE AND E. R. HUBBARD

Automatic handling for welding and punch-press operations is still a subject of prime interest to many engineering groups across the nation. A great deal of progress has been made in this field and many fascinating mechanical facilities have been created, sparking a continued interest among engineers and manufacturers.

Improvements in Production Operations

The concept of automatic handling for stampings and assemblies has brought about many improvements in production operations, the most important being safety and quality.

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Paper presented at the AWS National Fall Meeting held in Detroit, Mich., Sept. 28 to Oct. 1, 1959.

Through automatic handling, the employee is required to handle a part less, which results in minimizing the incidence of a safety hazard on the job.

The same holds true for quality: less handling reduces the incidence of damage to parts.

Equipment Features

The job of modifying welding fixtures and dies, through installation of automatic transferring equipment, is made less difficult if the engineer makes provisions for changes during the period when the tools are being designed.

Lifter and kicker installations, including disappearing gages in tools, are a necessity when automatic transferring equipment is used for both the loading and extracting operations.

There are times when it becomes necessary to relocate welding electrodes to provide proper clearance for the transfer of parts automatically. This can be accomplished without too much difficulty, especially in cases where more than one fixture is utilized to weld the panel completely. An air cylinder is generally used to operate the lifter and kicker equipment.

Clearance must be provided in the tools for the moving rails that transfer the finished parts. This is due to the fact that welding fixtures do not always allow enough space for this equipment. A good illustration of proper clearance is shown in Fig. 1.

Limit Switches and Actuators

An important item which sometimes causes downtime is the limit switch. Since many switches may be involved in a single operation, one may be the cause of bogging down an entire production line.

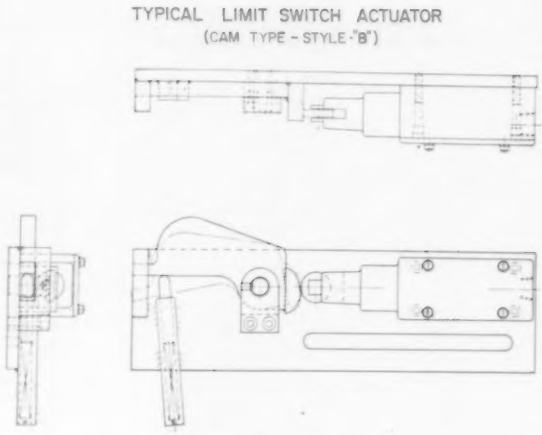


Fig. 2—Additional protection, and a better tripping condition of the switch, can be obtained by using an actuator

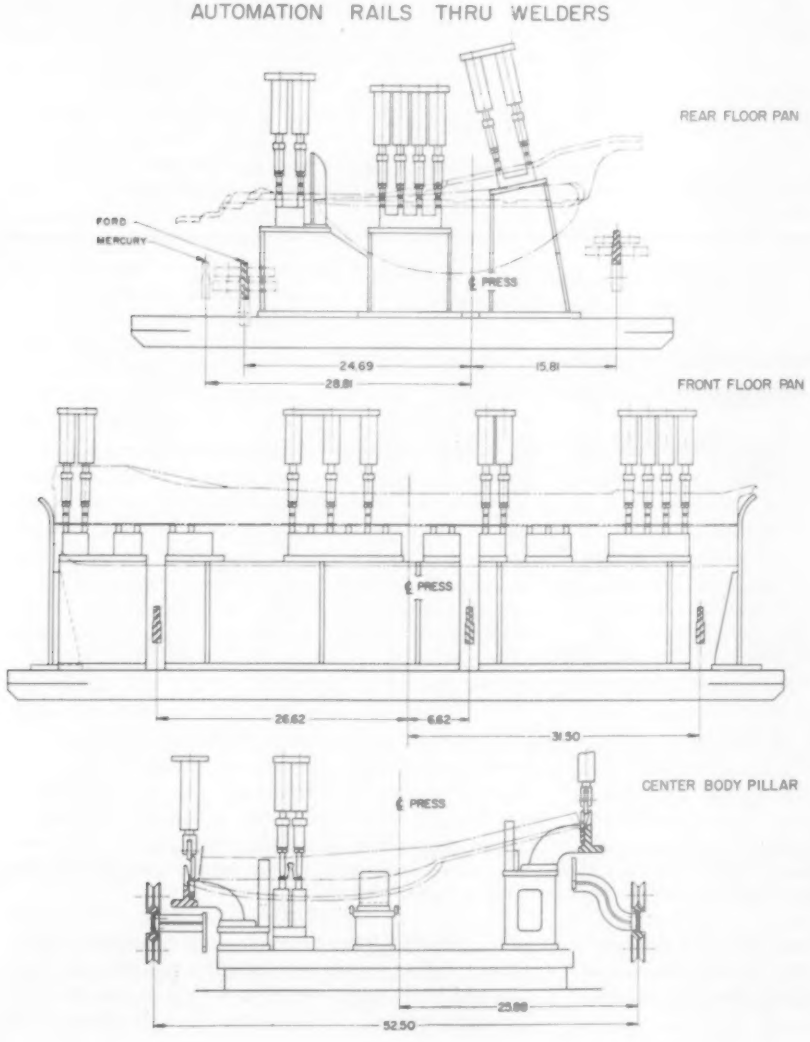


Fig. 1—Clearance provided in fixtures for rails that will transfer panels from one station to another

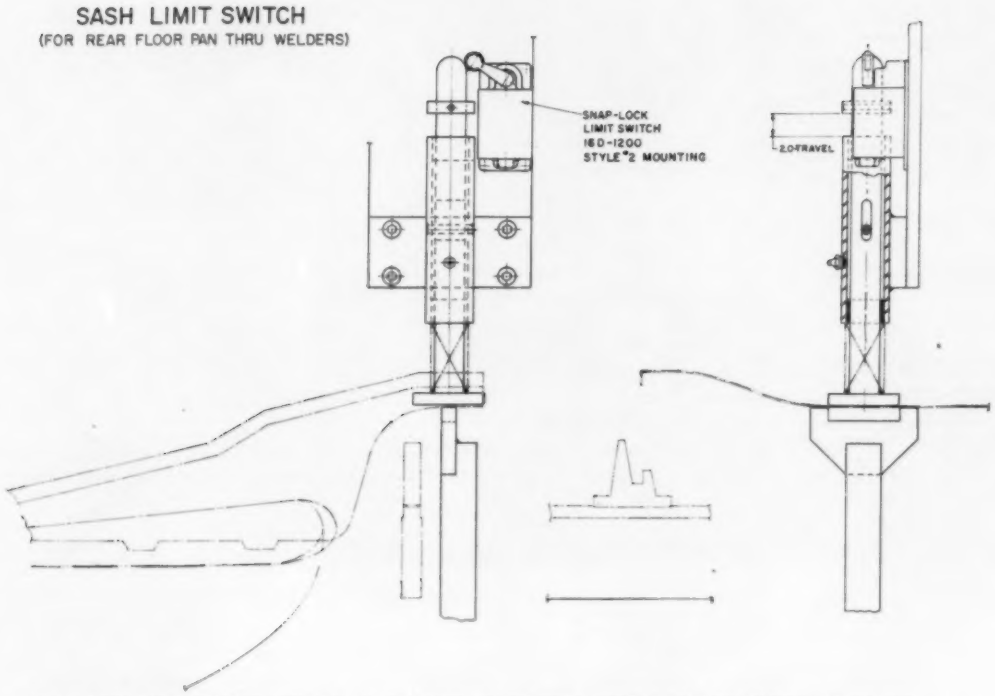


Fig. 3—Sash limit switches mounted in actuators are primarily used in welding fixtures. They can serve as a pressure pad, and also signal the "Go" sign in the circuit to protect the equipment and tools when panels stick to the electrodes

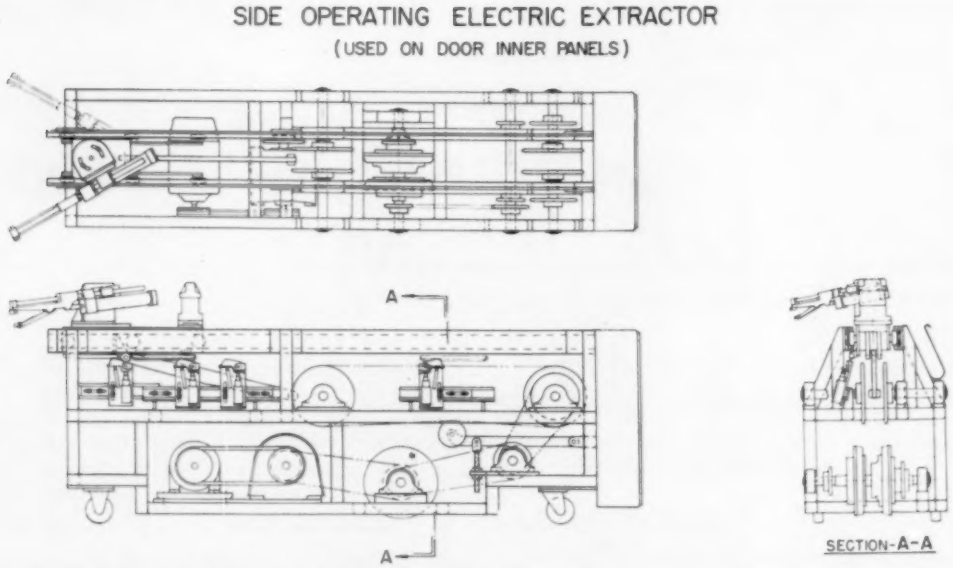


Fig. 4—The side-operating extractor can grasp a panel firmly at the corner to remove it from the die or fixture. This clears the way for the moving jaw assembly, and have it returned for the next panel, whereby the present panel can be turned over or transferred without any interference

The limit switches that have been installed to protect both operator and equipment on each press contribute much toward the elimination of personal injury and tool damage.

Practically all limit switches are mounted in actuators. This system reduces their exposure to damage which, in turn, contributes to a longer life span for each switch. This naturally cuts down costs

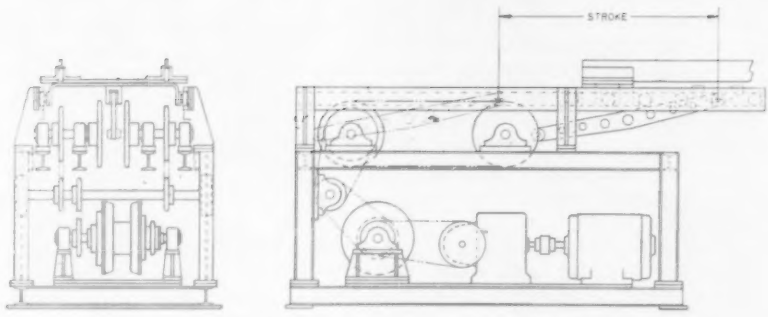
appreciably. At the author's plant, it has been found that switches last much longer when they are mounted in actuators. They also tend to improve the tripping action of the switches, which is so important in automatic handling.

There are many different types of actuators employed in automatic transfer operations. Each performs a specific job (see Fig. 2).

Sash limit switches, usually mounted in welding fixtures, protect both parts and tools from damage in many cases (see Fig. 3).

Actuators for sash switches are designed to provide a considerable retarding action. This is necessary to prevent the machine from operating at times when panels become stuck due to occasional malfunction of electrodes in the welding fixture. In these cases, the equipment will remain in a halted position until the panel is removed manually.

TYPICAL ELECTRIC DRIVE UNIT



ELECTRIC DRIVE UNIT WITH AN 8" DWELL

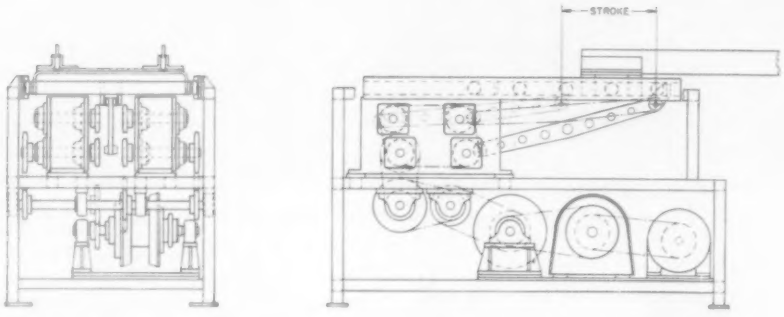


Fig. 5—A drive unit, driven electrically, is generally used for large-volume production

Quality workmanship in the construction of actuators should be emphasized. It must be remembered that a limit switch will operate only as well as the mechanical function that has been built into the actuator.

If uniform control is to be achieved in the automatic transfer of parts, proper timing and coordination are the main objectives. This is accomplished through the use of an electrically powered unit, utilizing clutch and brake. This system provides a uniform flow of parts from station to station.

Another important function of the sash switch is to prevent damage to electrodes when the welding fixture is operating automatically without a panel. This situation can be prevented by wiring the sash switch into the welding circuit. This will prevent electrodes from burning.

Extractors and Their Functions

The extractor has contributed more to the efficiency of the stamping industry than any other single unit. It has simplified the removal of parts from welding fixtures and dies. Utilizing extractors, parts are moved automatically from one station to another with positive controlled timing.

Vertical extractions have proved to be the answer for large-volume production. Panels are extracted and placed into the next station before the jaw is released. This is accomplished by stopping the momentum of the panel at the end of each stroke.

In order to accomplish this, a positive stroke is necessary. It is recommended that this unit be powered electrically to obtain a uniform and dependable motion. Through the use of chains and sprockets, the extractor has been simplified in design and results in a close resemblance to the transfer.

The unit shown in Fig. 4 is very flexible in that it can be moved about for use on either side of a press or, if necessary, for center extraction. Operating from either side of the press, the panel is extracted from the corner. The advantage of corner extraction is that provision is made for the jaw to return for the next panel without interference as the panel at hand is inverted.

For center extraction, two jaw assemblies are placed on the extractor carriage support. This

makes it possible for the unit to extract two panels simultaneously, dropping them to a motor-driven belt or transfer beneath the jaw.

The carriage support should have a vertical bar mounted on the top for each jaw assembly in order to extract the panels from the die.

Limit-switch actuators (see Fig. 4) mounted on slide plates are provided for adjustment purposes. The two end switches stop each stroke. Other switches in the unit control the forward motion of the carriage and position the panels for further transfer. This is accomplished by utilizing a time delay circuit.

Most extractors have different operating methods. Some are powered electrically, while pneumatic cylinders are used in other cases. It depends mainly on the size of the part, method of operation and the volume of production.

Important components in automatic handling are the lifters and disappearing gages in the welding fixtures and dies. It is vital that they be synchronized electrically with the loading and extracting facilities, both in the welding fixtures and on the presses. Lifters for large panels are commonly used for loading and extracting. They should be timed to operate at precise intervals, and provisions should be made for adjustments in timing when necessary.

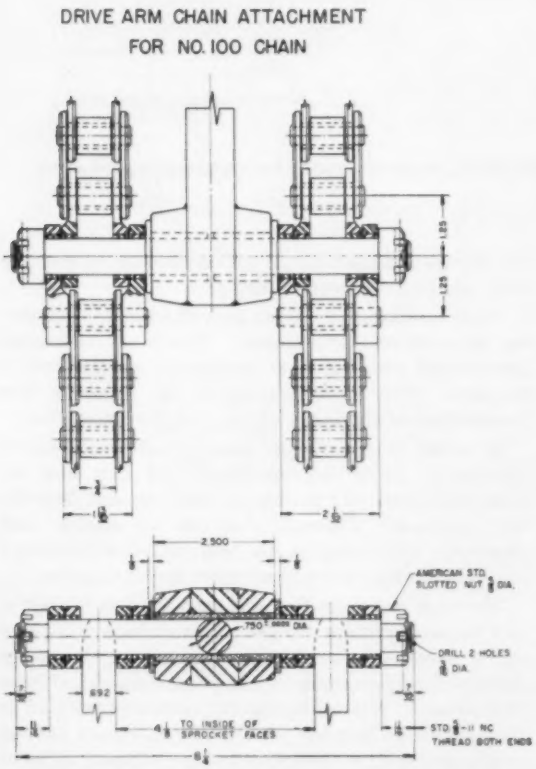

DRIVE ARM CHAIN ATTACHMENT
FOR NO. 100 CHAIN
2.500
AMERICAN STD SLOTTED NUT ⅝ DIA.
DRILL 2 HOLES ⅜ DIA.
TO INSIDE OF SPROCKET FACES
STD ⅝-11 NC THREAD BOTH ENDS

Fig. 6—A drive-rod connection for a link chain is being used on loaders, extractors and other units in other automatic chain-driven transferring equipment.

Transfer of Parts

A motor, reducer, clutch and brake assembly, are used to operate the unit that transfers parts through welding and press cycles, the motor running continuously. Traveling rails, that operate with a reciprocating motion, will transfer the panels, and are mounted on a trolley which is fastened to a connecting rod from a chain-and-sprocket assembly (see Fig. 5).

A large-diameter sprocket, uniting an endless chain with a connecting rod, produces a mechanical motion which permits the rails to slow down gradually at the end of each stroke. It is designed simply and is built sturdily to withstand the wear and tear of heavy production. The chain connection and connecting rod are illustrated in Fig. 6. It shows special links that provide a pin strong enough to endure the continuous start and stop motion. These pins should be hardened and ground.

A similar drive, which has been designed to accommodate a delaying action at each end of the stroke, is shown in the bottom portion of Fig. 5.

When a more definite stop is assured at the end of each stroke, accuracy and dependability are achieved in the proper location of panels in welding fixtures and dies. Of course, we are talking about a difference of $^1/_8$ of an inch variation in the length of stroke, and with most panels this variation is permissible.

A standard link-chain assembly (shown in Fig. 6) is used for the various units which vary in size from $^3/_4$ to 2-in. pitch chain, and good results have been attained. Such a chain assembly, complete with pin and 2 ft of chain, can be purchased commercially.

This type of drive, which involves timing for the intercepted stops, will do a satisfactory job. Electrically powered units for the transfer, loading, extracting and inverting of sheet-metal panels are preferred and are in common use.

Conclusions

There are many advantages to be gained when employing the aforementioned tools in automatic handling operations. At Ford's Buffalo stamping plant, employees set a new world safety record for the formed and stamped sheet-metal-product industry: working 10,709,877 man-hours without a disabling injury. There is no doubt that automatic-handling activities contributed greatly to the achievement of this record.

In addition to the advantages automatic handling offers for safe operations, quality also has greatly improved. Since 1952, when the first automatic transfer equipment was installed at the authors' plant, quality has become better and better with each passing year as the handling techniques were improved.

There is no doubt about it—the concept of automatic handling in all manufacturing operations is just around the corner. As more people in industry learn of its value in safety, quality, convenience and as a cost saver, its application will become widespread.

Fig. 1—4000-w ultrasonic spot-type welding machine with electronic power source shown in the background

Ultrasonic Welding

of Dissimilar-Metal Combinations

finds growing application in structural, electrical and electronic fields

BY W. C. POTTHOFF, JOHN G. THOMAS AND FLORENCE R. MEYER

SYNOPSIS. Ultrasonic welding techniques are being effectively used for joining dissimilar metals that are difficult or impracticable to join by more conventional techniques. Such junctions are generally free from the interdiffusion, intermetallic compounds and brittleness that often result with fusion bonding. Potential applications are found in structural, electrical and electronic fields.

Ultrasonic bonds of structural integrity have been produced in bimetal combinations of many of the high-temperature refractory metals and alloys such as titanium, zirconium, molybdenum and the precipitation-hardening stainless steels—materials of particular interest in the design of aircraft, missiles, rockets and nuclear reactors.

Electrical connections, such as the attachment of leads to coils or contact buttons to a variety of configurations, are readily produced with combinations of silver, copper, aluminum and other materials. Good quality junctions of excellent conductivity are reproducibly achieved, even through certain insulating coatings.

The process is also effective for precision joining of very fine wires and thin foils to materials such as transistor elements or certain types of printed circuits, without the unacceptable contamination resulting from certain fusion-joining methods. The assembly of electronic-tube, bridgewire and precision-instrument components present other significant possibilities.

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Paper presented at the AWS National Fall Meeting held in Detroit, Mich., Sept. 28 to Oct. 1, 1959.

Introduction

Expanding technology in the fields of missiles and rockets, atomic energy, and electronics has created new problems for the metal-joining engineer, particularly in areas involving dissimilar-metal junctions. Conventional techniques are often difficult to apply

Fig. 2—100-w ultrasonic spot-type welding machine used for precision joining of miniaturized components

or produce unsatisfactory bonds for specific applications.

With fusion welding, limitations are imposed by the specific technique used, the compatibility of the materials to be joined and the resulting joint properties. The degree of mutual solubility and formation of alloy phases under the nonequilibrium conditions that exist during fusion are particularly significant, since the presence of intermetallic compounds in a weld often results in poor mechanical strength, brittleness, and increased corrosion susceptibility.[1]

With resistance welding, which is currently the most common method for joining thin, dissimilar sheet materials, the heat balance may require adjustment by such techniques as the use of a smaller electrode contact area or a lower conductivity electrode in contact with material of higher conductivity.[2] Copper-aluminum junctions are usually extremely brittle, despite such techniques; the joining of these metals usually requires a special dual-pressure system to expel the brittle copper-aluminum phase from the weld zone.[2]

Other bimetallic junctions may be achieved by brazing, pressure bonding or mechanical joint methods, but these processes do not always provide the desired joint characteristics for a special application.

Recent developments in ultrasonic welding have led to successful bonds of dissimilar-metal combinations without some of the difficulties associated with conventional joining processes. It is particularly significant that such bonds are produced without fusion; thus, the undesirable characteristics of mutual alloying are minimized and no brittle cast structure is formed. Ultrasonic welding should not be considered a substitute for conventional techniques, but rather a supplementary process to be used where other methods are impractical, unreliable or too expensive.[3]

Ultrasonic welding has potential application in the fields of structures, electrical components and electronic assemblies. This paper is primarily concerned with the progress made along these lines.

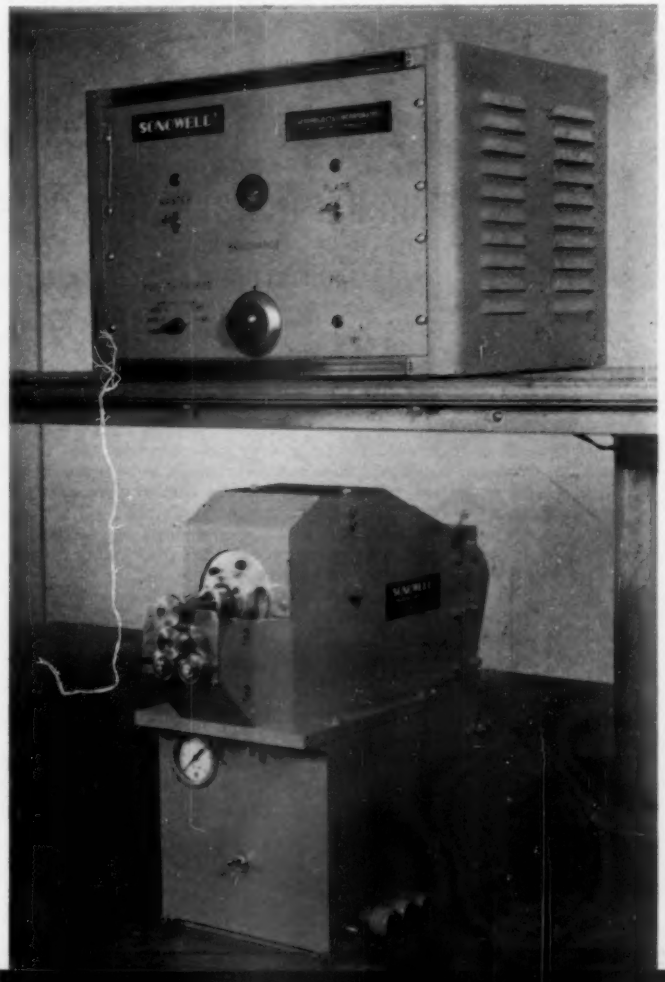
Description of the Process

Before going into these applications, it is pertinent to review the basic techniques and equipment used in the process and to summarize the characteristics of bimetal weld joints.

Ultrasonic welding is accomplished by introducing vibratory energy into the materials in the area to be joined, in a plane essentially parallel to the plane of the interface. This is achieved by a transducer-coupling-tip system which converts high-frequency electrical power from a suitable source into mechanical vibration and delivers it in the desired mode to the weld zone. In addition, a static clamping force is required to hold the materials in contact during the application of ultrasonic energy. The process is effective for producing spot-type welds, overlapping-spot seam welds, and continuous-seam welds with a roller-type welding tip.

Commercial equipment has been developed to operate in the frequency range of 15 to 60 kc per sec. Generally, the lower frequencies are used for equip-

Fig. 3—100-w double-roller, continuous-seam welding machine used for producing seam welds in thin-foil materials



ment operating at high power, such as the 4000-w spot-type welding machine illustrated in Fig. 1. In external appearance this welding machine resembles a resistance spot-welding machine, although the equipment is simpler to operate than an aircraft resistance spot-welding machine for aluminum. The only controls requiring adjustment are the power level, the clamping force and the weld pulse time. Somewhat higher frequencies are utilized in the spot-type welding machines used for joining small components such as transistor leads, thin foils or instrument parts. A miniaturized 100-w welding machine developed for such purposes is shown in Fig. 2. This machine may be equipped with a microscope for precision joining of very fine wires and the like.

Continuous-seam welding equipment incorporates a rotating transducer-coupling system, and the welding tip sometimes consists of a resonant disk attached to the end of an exponentially tapered coupler. Continuous vibratory power is applied longitudinally along the axis of the coupler, and the work either passes between two roller disks, one or both of which may be ultrasonically active, as shown in the small seam-welding machine of Fig. 3, or it is carried under an active disk on a traversing table, as illustrated in Fig. 4. The seam welds produced by this method are continuous, and the joints are leak-tight to the limit of detection by mass-spectrometer leak testers.

Degreasing of the parts to be welded is usually essential, although other precleaning is generally unnecessary unless the material contains a heavy-scale deposit. In such case, chemical cleaning or mechanical scale removal is necessary.

Basic research investigations of the ultrasonic-welding mechanism are currently in process,[4] and the significance of the various factors influencing the bonding is not yet fully understood. However, significant progress has been made in delineating the forces acting on the metal during welding and the metallurgical phenomena achieved. The applied vibratory energy combined with the normal static force induces rapid stress reversals along the bond interface, and mating surface films in the weld area are broken up and dispersed. Rupture of these films is accompanied by local plastic deformation, and substantial interpenetration of the weldment members may occur, although thickness deformation of the joint is usually negligible—generally less than 5%. The metallographic characteristics of a bond are determined by both the welding conditions employed and the relative properties of the materials and surface films.

It has been established that a localized temperature rise occurs in the weld zone during ultrasonic welding, although interface-temperature measurements, coupled with metallographic observations, have shown no evidence of fusion. Furthermore, the magnitude of the temperature rise can be controlled within limits by appropriate selection of welding-machine settings. Figure 5 shows typical temperature-rise curves during a 1-sec welding pulse in aluminum, copper and ingot iron. The two curves in each case resulted from different values of power, clamping force and weld time, which produced welds of equivalent quality. This temperature effect is being studied further.

Such localized heating of the contact surfaces lowers the stress level required for plastic flow and permits greater interpenetration and interfacial film disruption. It also introduces the possibility of diffusion reaction, such as oxide solution and solid-state alloying. However, conventional diffusion coefficients appear to limit the movement of thermally motivated atoms in the brief time available during formation of a spot-type weld, usually less than 1 or 1.5 sec. The available techniques for controlling the maximum temperature achieved can be used to minimize such diffusion reactions.

Ultrasonically Weldable Combinations

Ultrasonic welding permits the production of sound metallurgical bimetal junctions of structural integrity and/or good conductivity, with no cast structure, little or no interdiffusion and negligible formation of intermetallic compounds. High-quality

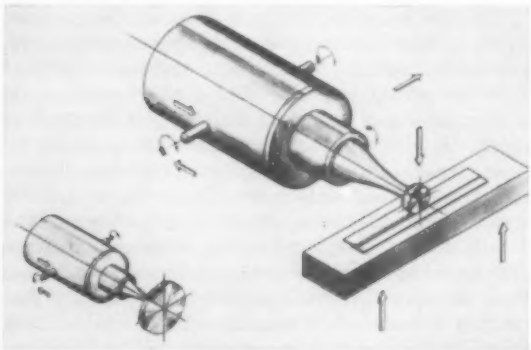


Fig. 4—Schematic diagram of traversing-table continuous-seam welding machine

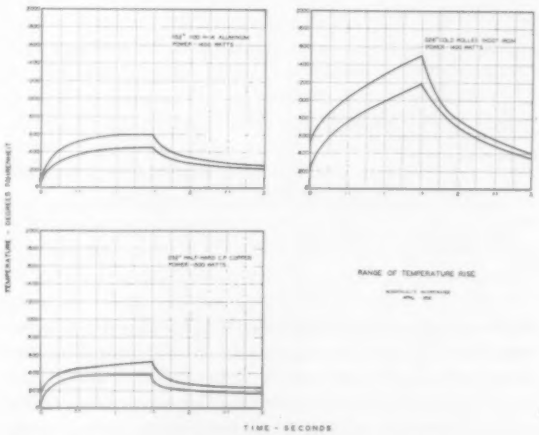


Fig. 5—Temperature rise in three materials during formation of ultrasonic spot-type welds

Table 1—Some Dissimilar-metal Combinations That Have Been Ultrasonically Welded

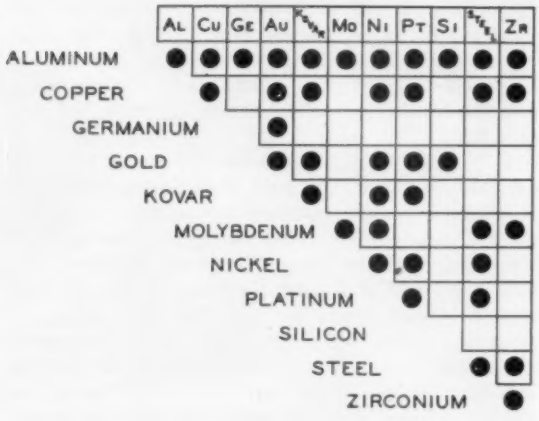


Table 2—Ultrasonic-weld Strengths for Typical Bimetal Combinations

Material combination	Shear strength,[a] lb	Min. average[b] MIL-W-6858A, lb
0.030-in. 6061-T6 Al alloy to 0.030-in. 321 stainless steel	870 ± 10[c]	295
0.040-in. 3003-H14 Al alloy to 0.028-in. AM-350 stainless steel	700 ± 30	375
0.050-in. 2024-T3 Alclad Al alloy to 0.040-in. low-carbon steel	860 ± 150	585
0.061-in. 1100 H14 aluminum to 0.042-in. copper	845 ± 10	495
0.028-in. A11O-AT Ti alloy to 0.025-in. 430 stainless steel	940 ± 20	495
0.013-in. J-1500 to 0.001-in. Inconel X to 0.013-in. J-1500	650 ± 130	
0.013-in. J-1500 to 0.001-in. nickel to 0.013-in. J-1500	770 ± 60	
0.040-in. 2014-T6 Al alloy to 0.001-in. 1100-H19 Al to 0.040-in. 2014-T6 Al alloy	1330 ± 90	435
0.063-in. 2014-T6 Al alloy to 0.001-in. 1100-H19 Al to 0.063-in. 2014-T6 Al alloy	1310 ± 120	840
0.025-in. molybdenum to 0.0025-in. nickel to 0.025-in molybdenum	530 ± 30	

[a] Mean strength with 90% confidence interval.
[b] Based on strength required for monometal welds in the weaker material.
[c] Data supplied by the Martin Co., Denver, Colo.

bonds of this type have been achieved with a wide variety of dissimilar metals and alloys, including the commonly used metals such as aluminum, copper and steel; precious metals such as gold, silver and platinum; and high-temperature refractory metals such as molybdenum, tantalum, titanium and the precipitation-hardening steels.

Table 1 shows graphically some of the combinations in which bimetal welds have been successfully achieved. The blank spaces do not necessarily mean that the combinations are impossible to join; in most cases, such welds have never been attempted. The metal elements listed in the table are understood to include the major alloys of these elements. For example, aluminum includes both structural and nonstructural aluminum alloys; copper includes several types of brass, such as gilding metal and cartridge brass; nickel includes the nickel-base alloys such as Inconel and Hastelloy; zirconium includes the more commonly used zircaloys. Bimetal welds within each group are also possible, such as junctions between two types of steel of widely different properties.

Structural Applications

As noted above, the weldable combinations include many of the high-strength, high-temperature refractory metals of particular interest in missile and rocket design and in nuclear reactor structures.

The material thicknesses that can be satisfactorily joined are limited by the power-handling capacity of presently available ultrasonic welding equipment, but these restrictions apply only to the thinnest member of the weldment; the other member may be of heavy sheet or block. The thickness limitation for a given material depends on its physical and metallurgical properties. Aluminum and copper alloys can be joined in thicknesses up to about 0.100 in. while the present limitation for iron and nickel-base alloys or for titanium and zirconium alloys is approximately 0.040 in. Bimetal joining is further limited by the relative hardnesses of the components. Materials of widely different hardnesses are difficult to join without increased thickness deformation of the softer component. Within present capabilities of the equipment and the process, ultrasonic welds show high shear strengths entirely acceptable for structural joining. Furthermore, this type of welding produces considerably less degradation of the strength of the base metal than do fusion-joining methods, since the heat generated during welding is extremely localized, does not exceed the melting point and can be controlled within limits.

The significant strengths achieved with single-spot welds in representative material combinations are evident in Table 2. Moreover, the reproducibility of weld strength is good, the 90% confidence intervals in most instances being less than 10% of the average value. It will be noted that the military specifications for resistance-weld strength in monometal combinations of the weaker material are provided for comparison. It is recognized that such a comparison is not entirely justified because of several distinct differences between ultrasonic and resistance welds. It is strongly believed that ultrasonic welding has reached a state of development at which military specifications should be developed solely for junctions produced by this process, taking into account their unique characteristics. These include various weld-

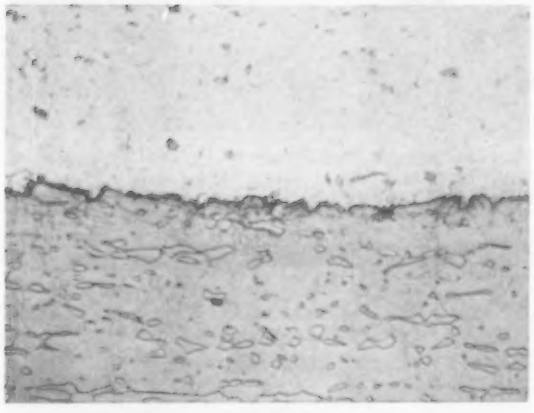


Fig. 6—Ultrasonic bond between 0.040-in. 3003 aluminum alloy (top) and 0.038-in. AM-350 stainless steel. Electrolytic-oxalic acid etch, X 670. (Reduced by 1/3 upon reproduction)

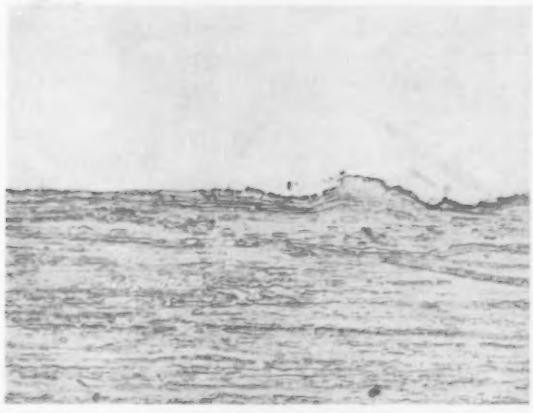


Fig. 8—Ultrasonic bond between 0.040-in. nickel wire (top) and 0.020-in. molybdenum. Nickel unetched, molybdenum etched in KOH + $K_3Fe(CN)_6$, X 500. (Reduced by 1/3 upon reproduction)

Fig. 7—Ultrasonic bond between 0.024-in. AISI 430 stainless steel and 0.28-in. A-110AT titanium alloy. Steel, unetched; titanium alloy, HF + HNO_3 etch, X 150. (Reduced by 1/3 upon reproduction)

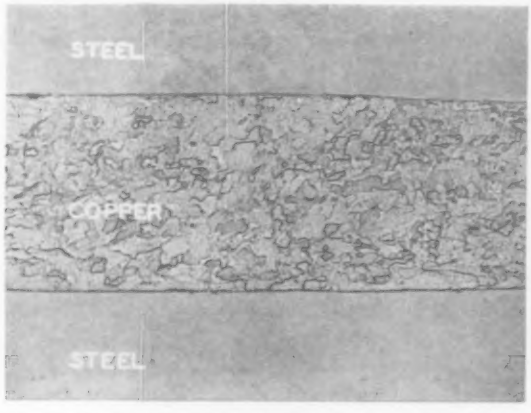


Fig. 9—Ultrasonic-bond joining two sheets of 0.005-in. AISI 316 stainless steel to 0.010-in. copper. Electrolytic-oxalic acid etchant, X 250. (Reduced by 1/3 upon reproduction)

ing geometries, relative ease of producing overlapping-spot and overlapping-seam welds, possible variation in weld area by using increased power with no detrimental effect on the weldment, and the relatively unimportant effect of edge distance and spot spacing. However, until military standards for ultrasonic welding are established, it is convenient to use certain portions of MIL-W-6858A for resistance welds as a temporary guide for evaluating weld quality.

Two types of joints are represented in Table 2. The first five items are simple lap joints between two different materials. Figures 6–9 are representative photomicrographs of welds of this type. In the aluminum-to-stainless steel weld in Fig. 6, it is apparent that registry across the interface has been accomplished by preferential yielding of the softer aluminum alloy. The titanium-to-stainless steel weld in Fig. 7 illustrates the effect of rather high localized temperatures which are sometimes obtained with materials of low thermal conductivity. The compositional gradient in the titanium alloy reveals the extent of the heat-affected zone, the acicular structure adjacent to the interface having resulted from cooling through the transformation temperature. The nickel-to-molybdenum weld of Fig. 8 shows characteristic interfacial deformation, which is entirely lacking in the bonds between copper and steel in Fig. 9. Neither of these two photomicrographs shows any effect of heating on the metal microstructure.

The last five items in Table 2 represent foil-insert weldments in which a foil interleaf of a different material is interposed between two members of the same material. Figure 10 shows an example of a weld between two sheets of 0.040-in. 2014-T6 aluminum alloy with a 1-mil 1100-0 aluminum insert. It will be noted that the foil has been reduced approximately 80% in the bond zone, while the over-all thickness reduction of the sheet is less than 5%. The specific role of the foil in the bonding mechanism is not clear. However, it has been established that the interleaf

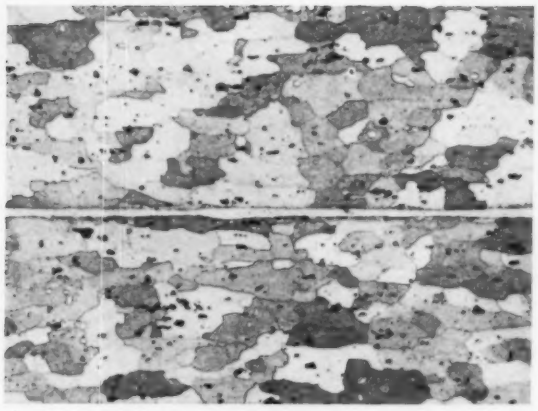


Fig. 10—Two sheets of 0.040-in. 2014-T6 aluminum alloy ultrasonically bonded with 0.001-in. 1100-0 aluminum insert. Keller's etch, X 350. (Reduced by 1/3 upon reproduction)

Fig. 11—Ultrasonic bond between aluminum wire (above) and copper. Etched in 0.5% HF, X 900. (Reduced by 1/3 upon reproduction)

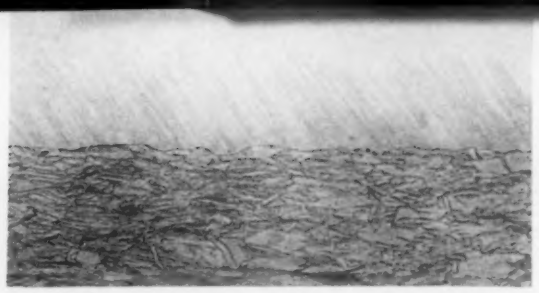


Fig. 12—Ultrasonic bond between silver contact button (top) and copper plate. Etched in NH_4OH + H_2O_2, X 300. (Reduced by 1/3 upon reproduction)

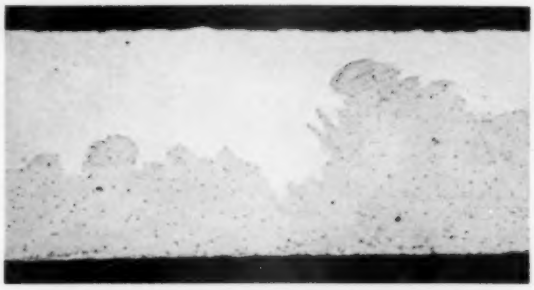


Fig. 13—Ultrasonic bond interface between 0.003-in. foils of nickel (top) and gold-plated iron-nickel-cobalt alloy. Unetched, X 300. (Reduced by 1/3 upon reproduction)

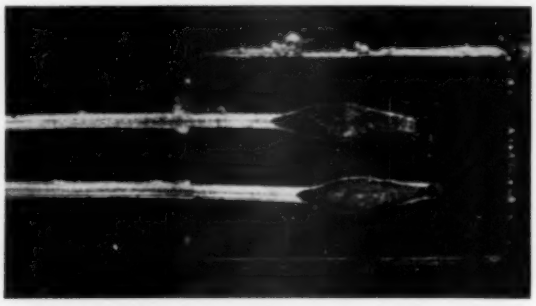


Fig. 14—Twin aluminum-lead wires ultrasonically bonded to silicon wafer

permits extension of the range of weldable sheet gages in certain materials or permits welding at lower power or in shorter weld times.

Interleaf welding has also facilitated the joining of two or more dissimilar metals. For example, continuous-seam laminations of stainless steel to molybdenum to zirconium plate have been successfully achieved by using aluminum foil inserts between the stainless steel and the molybdenum and between the molybdenum and the zirconium.

Because of the practicability of producing ultrasonic bimetal junctions that are difficult or impossible to achieve by other techniques, specific structural applications are of active interest to the automotive industry, to reactor engineering groups and to aircraft manufacturers particularly concerned with space vehicles.

Electrical Connections

Junctions between aluminum, copper and/or silver have long been a problem in electrical assemblies, since not only adequate strength but also good conductivity is required for current-carrying members. Silver and copper are usually difficult to weld by resistance methods because of their high electrical and thermal conductivities. Furthermore, thin-gage foils used in transformer coils, paper-wound capacitors and similar parts, usually contain an insulation coating of an organic material, and aluminum is often anodized to provide insulation. These coatings must be removed to permit welding by resistance methods and, even then, a good connection is difficult to achieve because of the thinness of the foils involved. With certain coatings, ultrasonic welding has produced sound joints of good conductivity without the necessity for removing the insulation.

While investigating the attachment of leads to ribbon-coil transformers, McCarthy *et al.*,[5] made a study of the electrical characteristics of joints between bare or organically coated aluminum foil, 1/4 and 1/2 mil thick, and bare or plated copper 2 to 3 mils thick; the joints were produced by each of three

methods: soldering, capacitor discharge and ultrasonic welding. The results of their investigation indicated that ultrasonic welds could be produced through the surface coatings with no damage to the foil and without introducing impurities to shorten the life of the joint. The conductivity of the ultrasonically welded joints was comparable to that achieved by capacitor-discharge welding, even though only two ultrasonic welds were used for a junction requiring six capacitor discharge welds. Furthermore, the ultrasonic junctions showed less variability during 6380 hours of testing. Soldering proved to be less reliable than either of the other two processes. Ultrasonic welding was concluded to be practical and readily adaptable to automatic operation, since reproducible joint quality was achieved for an indefinite period after initial setting of the welding conditions.

The above work was oriented to the attachment of leads to transformer coils. Aluminum-to-copper junctions are of interest in assembling other coils of foil material. The character of such a bond is illustrated in Fig. 11. In this case, the interfacial disturbance has been severe enough to tear off pieces from the copper surface and embed them as islands in the aluminum.

Contact buttons may be readily welded to sheet, plate, ribbon or other configurations. In one instance, gold contacts were bonded to gold-plated beryllium springs. A typical ultrasonic weld between a silver contact button and a copper plate is shown in Fig. 12.

Another important application of ultrasonic welding is the joining of various metals to an iron-nickel-cobalt alloy often used where glass-to-metal seals are required. Figure 13 illustrates a typical ultrasonic bond between 0.003-in.-thick sheets of nickel and the gold-plated iron-nickel-cobalt alloy. The interpenetration of the mating surfaces during the welding of thin foil is generally quite high, in this particular instance being approximately 75% of the sheet thickness. The plastic turbulence in the weld zone has resulted in the dispersion of the gold plating along the interface. It is significant that such large internal displacements can occur without appreciable reduction in the over-all sheet thickness. This is particularly important in thin foil bonding.

The process is of interest for other types of electrical connections, such as the joining of stranded aluminum wire to copper terminals. Such junctions as these are entirely within the capabilities of available ultrasonic-welding equipment, and other areas of applications will undoubtedly become evident in the future.

Electronic Applications

The miniaturized components used in the electronic industry present additional challenges to joining methods. Ultrasonic welding has many advantages to offer in this field, and the small welding unit of Fig. 2 permits precision joining even of wires almost too fine to be seen by the naked eye. The process is well suited to automated-assembly procedures because once the proper welding conditions are established, joints of high reproducibility can be obtained.

The fabrication of transistors has been a particularly vexatious problem. Special precautions are taken to achieve semiconductor materials of atomic purity, and difficulties have been encountered in avoiding contamination and structural damage during attachment of leads to these elements, closure of the housings and sealing of the evacuation tubes. Fusion-joining methods result in arcing, sparking and outgassing due to the melting of the metal. The soldering techniques currently used are time consuming, require a high degree of operator skill and even so result in very high rejection rates.

Ultrasonic welding has been applied successfully to these transistor-assembly problems. In particular, high-quality attachments of fine-wire leads to silicon and germanium transistor materials have been achieved, and the ultrasonic technique is being introduced into production fabrication in a number of electronic plants. The leads can be precisely positioned and bonded in very small areas without the contamination resulting from outgassing of molten metal or the arc, spark and sputter resulting from the passage of electric current through the joint. The bonds are clean and show no penetration of the lead material into the semiconductor. Joint strengths are superior to the strength of the lead wires, and the ohmic contacts are markedly superior to those produced by other techniques. Representative junctions between two 0.0025-in. aluminum wires and a silicon wafer are shown in Fig. 14.

Another important application in the electronic field is the assembly of bridgewire or electric-match components, in which fine-wire filaments must be joined to terminal posts. The filament wires are usually about 0.001 in. in diameter, made of such materials as nickel-chromium or tungsten-platinum alloy. The terminal posts may be of copper, iron, phosphor-bronze or other materials. Fig. 15 shows examples of several types of bridgewire assemblies fabricated by ultrasonic welding. With the aid of precision tooling, junctions of these types have been produced in pilot-plant quantities of up to 1000 units.

Potential applications of this technique exist in the manufacture of electronic tubes, which contain many welded connections. Ultrasonic welding of the components would eliminate the contamination which is such a serious problem in obtaining electronic tubes of high reliability. Furthermore, it would permit the use of materials such as titanium which are presently not usable because of the difficulty in welding these materials to dissimilar metals.

The welding of leads to high-temperature circuit boards is another promising application. Successful pilot runs have been made in the attachment of leads to metallized-glass printed circuits involving such metals as copper, chromium and silver. Delicate instrument components such as fine wire coils and aluminum pointers can be effectively bonded by this

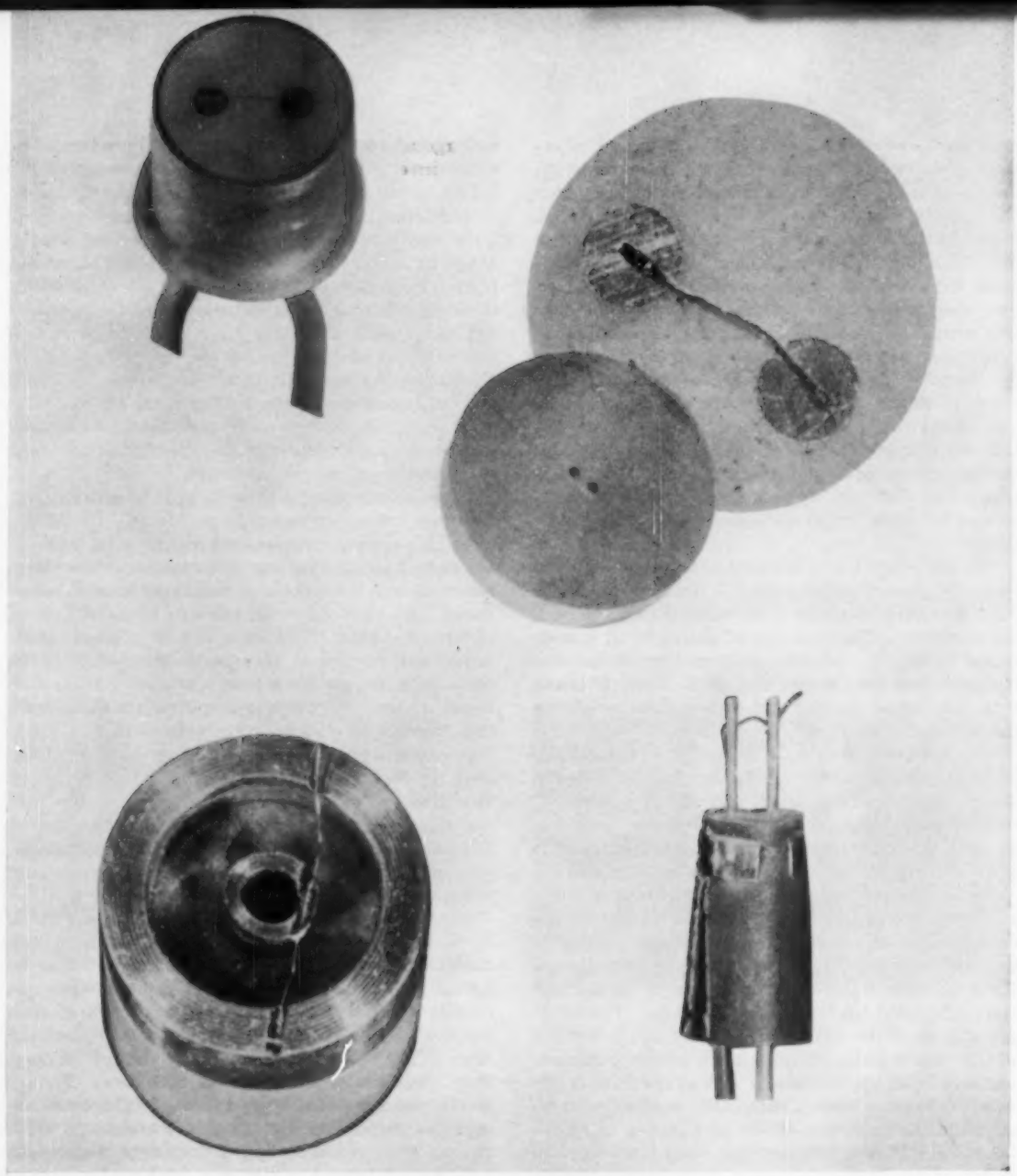


Fig. 15—Ultrasonically welded bridgewire and electric match assemblies

technique. Throughout the electronic industry, there are possibilities for ultrasonic welding in the joining of assemblies or components which are impaired by the high temperatures associated with fusion welding or even soldering.

Conclusion

These examples demonstrate the capabilities and the versatility of ultrasonic welding for dissimilar-metal-joining applications. Significant new developments and improvements in transducer-coupling systems are in process to permit welding heavier and thicker materials and a wider variety of joint configurations. These developments should increase still further the usefulness of this new joining method for structural, electrical and electronic applications.

References

1. Brown, W. F., *et al.*, "Spot, Seam and Projection Welding," *Welding Handbook Section 2*, AMERICAN WELDING SOCIETY, New York, N. Y., 4th ed., p. 30.56 (1958).
2. Resistance Welding Committee, AMERICAN WELDING SOCIETY, *Resistance Welding: Theory and Use*, Reinhold Publishing Co., New York, N. Y., p. 108 (1956).
3. Koziarski, J., "Some Considerations on Design for Fatigue in Welded Aircraft Structures," The WELDING JOURNAL, **38**(6), 565–575 (1959).
4. Aeroprojects Inc., "Basic Research in Ultrasonic Welding," Navy Contracts No. NOas 58-108-c and NOas 59-6070-c (in process).
5. McCarthy, D., Pirc, V., and Hannahs, W., "Ultrasonic Welded Aluminum-Copper Junctions as Electrical Connections," Third Electronic Industries Conference on Reliable Electrical Connections, Dallas, Tex., December 1958.

Practical Welder and Designer

Natural-Gas Cutting Equipment Aids Fabrication of Pipes

BY L. H. PAINE

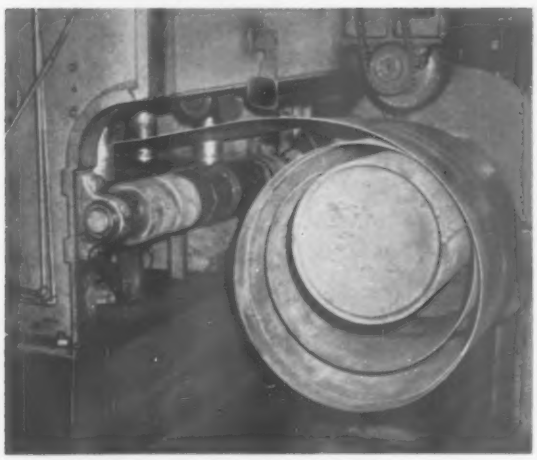


Fig. 1—Mild-steel sheets, cut and beveled with natural-gas torches are rolled and ready to enter the forming mill

Fig. 2—Twin cutting torches are mounted on a portable carriage to bevel and cut edges before pipe is rolled and formed

The Cal-Metal Pipe Corp. of Louisiana at Baton Rouge is a producer of pipe for high-pressure gas and oil lines (see Figs. 1 to 3). Sizes of its output range from 4 $^1/_2$ in. OD to 42 in. OD while wall thicknesses vary from 0.109 to 1.000 in.

The newest addition to the pipe-milling operation at the Baton Rouge plant incorporates the latest refinements in the progressive roll forming of welded pipe. One of these refinements is the use of natural-gas cutting equipment in the cutting to size and beveling of mild-steel plates prior to rolling and in the squaring-up and beveling of pipe-section ends once they have been formed. For both operations, torches specifically designed for use with propane or natural gas are used.

In the pre-forming operation twin style torches mounted on oxygen-cutting machines simultaneously cut and bevel the mild-steel plates which are produced in varying thicknesses (see Fig. 2). In the squaring-up operation completed pipe is straightened and outer edges are beveled by single torches mounted at each end of the finished pipe (see Fig. 3). Bevelers use a floating-head principle wherein the bevel remains true to the wall of the pipe regardless of minute out-of-roundness or of wall-thickness variations.

L. H. PAINE is Assistant Manager, Engineering Services, Air Reduction Sales Co., Baton Rouge, La.

Fig. 3—Natural-gas torch used to bevel ends of pipe after forming and squaring-up

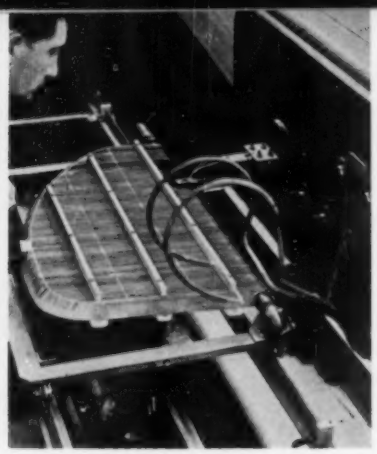


Fig. 1 Brazing of jet engine parts

Automatic Brazing of Air-Intake Grille for Jet Engines

Jet-engine components can be extremely difficult to produce. One such component is the air-intake grille, and several are used in all jet engines. Ordinary torch or oven methods of brazing the grilles are not satisfactory because they frequently warp the part itself.

A French manufacturer uses special procedures to solve this problem.

The work to be brazed consists of a steel band bent into a semicircle with ends brazed to a steel tube which acts as a hub or axle. Running from the tube to the band are many cross members comprising the grille. These cross members are brazed into slots cut into the band and have holes for the tube at their other end. To reinforce the strips, there are two cross ribs at right angles to the strips. These ribs are also slotted and brazed to engage and space the strips.

The work coil (right hand side of work station in Fig. 1) is adjusted to cause a concentrated heat zone along the upper cross rib. Preplaced silver-brazing alloy has been arranged together with a fluxing compound. Once the heat push button has been energized, the solder alloy flows around the joint areas. By adjusting his pace, the operator makes a perfect continuous braze along the entire cross rib. By inverting the assembly, he can accomplish a similar brazing operation on the lower cross member.

For heat treating, the carriage and rail mechanism are removed from floor mounts and other fixtures substituted.

Based on story by Induction Heating Corp. Brooklyn, N. Y.

Bulletin from Hawaii

Malihini? Kamaaina? or Aikane?

When you attend the American Welding Society's **First** Post Convention Tour in Hawaii this April, you'll find the Hawaiian people extremely friendly. In fact, they'll go out of their way to make your stay enjoyable. Newcomers are called Malihinis. . .old timers, Kamaainas . . .and warm friends, Aikanes. Because of Hawaii's relaxed, friendly way of life, visitors become "native" soon after they arrive. And—there's nothing that pleases the Hawaiians more.

You won't want to miss anything in this wonderful state. Be sure to take in . . .

ITS FABULOUS SHOPS AND STORES: Hawaii is a wonderful place to buy Oriental wares. The Watumull stores in downtown Honolulu are good places to buy hand-blocked linens and other textiles—Hawaiian sportswear, carved Hawaiian woods and lauhala bags.
ITS WORLD-FAMOUS RESTAURANTS: One of the best-known and most popular restaurant is Lau Yee Chai in Waikiki. Its outdoor dance floor has a vertical rock garden and waterfall. The food is superb. There are a number of picture Japanese tea houses. The Tropics, the Broiler, The Tahitian Lanai and the Colonel's Plantation are popular. The best places for cocktails in the Waikiki area are—the Royal Hawaiian Hotel, Captain Cook Bar in the Surfrider, the Bora Bora Bar at Don the Beachcombers and the Tiare Room Shell Bar.

You'll have plenty of time to be "on your own" while in Kauai and Honolulu. No activities have been planned for May 2 in Kauai. This is an island where you will do well to hire a U-Drive car or a private car. . .for you will have more fun and see more that way.

Several mornings and afternoons have been left free during your stay in Honolulu. . .so you'll want to take in **all** the top attractions there, also. A must on your list should be a trip to Chinatown. Although the buildings are not so distinctive as those in San Francisco, the small apothecary, jade, food and other shops are well-worth seeing.

But, then, everything's well-worth seeing in Hawaii. Our advice to you is—GO THERE—as a participant in the American Welding Society's **First** Post Convention this April.

ATOM·ARC* Pipe Welding Alloys

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Photos Courtesy NATIONAL VALVE & MANUFACTURING COMPANY

National Valve and Manufacturing Co., fabricator and erector of quality piping for American industry, has consistently been among the leaders in the piping industry for the last half century. This large, engineering-minded organization maintains its position of leadership through research to constantly improve methods and facilities—testing and selecting the latest in materials that will provide their clients with the finest quality high pressure, high temperature piping.

NAVCO research into welding techniques and materials resulted in the selection of ATOM·ARC All Position Iron Powder Low Hydrogen alloys for handwelding of pipe fabrications and for field erection. The X-ray quality of ATOM·ARC weld metal eliminates needless rework. The flat, smooth bead contour makes slag removal easy, requires no costly and time consuming chipping and grinding, allowing weldors more time for welding. Even finish grinding of the final pass is eliminated. These cost saving properties of ATOM·ARC electrodes are amplified by the fast deposition rate achieved from the iron powder type coatings.

These are the facts NAVCO found in their search for better materials for high quality piping . . . facts which prove ATOM·ARC Iron Powder Low Hydrogen Alloys produce superior piping products. For your free copy of an informative and revealing report to piping contractors, write to:

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Society News

Los Angeles to Become the World's Market Place of Welding Next April

Next April 26–28 the 41st Annual Meeting and Exposition will feature, in addition to the scheduled technical and social events, a Welding Show of spectacular proportions. Keeping pace with the exceptional growth of the welding industry in recent years, the exhibition of equipment and materials promises to be the largest ever held by the AMERICAN WELDING SOCIETY. The total area of the Great Western Exhibit Center exceeds 70,000 sq ft—room enough for a full-size football field and spectator area.

This is the first time the AMERICAN WELDING SOCIETY has held a Welding Show on the West Coast and the interest and enthusiasm shown by the industry indicate a highly successful exhibition.

The AWS Welding Show has come to be regarded as one of the top shows in the United States. It now ranks among the 10 largest in the country and has grown to the point where its space requirements have become a leading factor in the selection of sites. Originally it was thought that the annual show could be held in many different cities in all parts of the country. Within two years of its inception, the show outgrew such intentions and became too big for any but the larger cities which possess adequate convention facilities.

One of the principal reasons for the high effectiveness of the Welding Show is that AWS had adhered firmly to the policy of restricting exhibitors to those in the welding industry and closely related fields. There would be no difficulty in selling any amount of space for exhibits not truly related to welding.

Exhibitors return year after year—over 58% of them have been in all AWS Welding shows. With their continued participation, and with the addition of new exhibitors each year, the Show has become the world's market place of welding. Every effort is made to restrict the attendance to those interested in welding and to exclude the general public. This gives the Show the unique distinction of having practically 100% of the visitors professionally interested in some facet of a single industry.

Everyone attending the Welding Show registers before entering the exhibit hall. The registration cards are studied after the meeting, and attendance and occupational analyses are prepared. Information derived from these reports is of great assistance to exhibitors, since it guides them in handling their promotional activities.

The occupational breakdown is of extreme importance—it is an excellent guide to the purchasing power of those attending. Records show that almost everyone attending the AWS Welding Show has the power to influence purchasing. Whether it be the actual authority to purchase, or the ability to specify or make recommendations, each in his own way has a direct influence upon sales. This unusual purchasing power is to be found only in a show where both exhibitors and attendance are restricted to a particular field.

The AWS Welding Show has won wide recognition, both inside and outside the USA. Many publications carry notices on the Show and more and more visitors from overseas attend each year.

It is now expected that, next April, $3,000,000 worth of welding equipment will be on display in Los Angeles. A large number of manufacturers have new equipment and developments under wraps at the present time, ready to be displayed for the first time at the Show. Other companies are busily engaged in completing their development programs and getting their exhibits ready. One thing is certain—many new products, processes and equipment to be used this coming year will be revealed for the first time at the Welding Show in April.

While the Welding Show is scheduled for April 26–28, the technical and social events will take place from April 25–29. During this week the Biltmore Hotel in Los Angeles will be the scene of such activities as the presentation of the Adams Lecture by Robert D. Stout, the reading of 69 papers on welding topics, the meetings of various committees and the banquet. An interesting ladies' program has been developed and a number of plant tours have been arranged by members of the Los Angeles Section who are acting as hosts for the entire annual event.

Last year's Chicago Show Was a Great Success. . .

. . .the 1960 Show Promises to be Even Greater!

The center of AWS activities- - - the Biltmore Hotel

The Great Western Exhibit Hall

World-famous Wilshire Boulevard

You'll want to visit Disneyland

KEEPING YOU POSTED

by Fred L. Plummer

● These notes are being written on Saturday, December 19th. Just before noon today another outstanding welded vessel, the atomic powered attack submarine *Scorpion* moved smoothly down the ways at the shipyard of the Electric Boat Division of General Dynamics Corp. in Groton, Conn.

● AWS Sections and individual members are responding generously to the drive for funds for the United Engineering Center. Vice-president Al Chouinard is providing fine leadership and is receiving excellent support from our District Directors and Section Officers. The ten honor sections with percent of goal pledged as of December 15th were: Hartford 100, Kansas City 100, Niagara Frontier 100, No. Central Ohio 100, Pascagoula 100, Toledo 100, Philadelphia 89, No. New York 86, New York 81, Maryland 61. (Detroit also has 100 in process.)

● The January issue of the Welding Journal included the technical papers program of the 1960 Annual Meeting and Welding Exposition which will be held April 25–29 in Los Angeles. Hotel reservation forms and a brochure covering the post-conference holiday and Mid-Pacific Conference in Hawaii were mailed to members during December. Other issues of the JOURNAL have provided additional information concerning these events. Advance reservations are heavy. It seems probable that all attendance records may be broken. Be sure you obtain preferred reservations. Do not delay your requests.

● Your Secretary and Mrs. Plummer spent the last several days of November enjoying a very pleasant Grace Line cruise on the ship *Santa Rosa*, with visits at Curacao, La-Guaira and Caracas, Aruba, Jamaica, Nassau and Port Everglades.

● The welding industry has lost another of its long time active and influential members in the death of John Tinnon. President C. I. MacGuffie and Past-president J. H. Humberstone joined many other AWS members at the funeral held December 2nd in New York.

● On December 3rd, Convention Manager Frank Mooney and your Secretary met with representatives of the Sheraton-Atlantic Hotel to discuss facilities for the 1961 Assembly of the International Institute of Welding which will be held in New York April 11–16 immediately preceding the AWS Annual Meeting and Welding Exposition. Headquarters for the AWS will be located in the Commodore Hotel with the Exposition located in the Coliseum.

● The following day Technical Secretary Ed Fenton and JOURNAL Editor Bonney Rossi traveled with A. N. Kugler to Philadelphia to present a panel program for which AWS Technical Activities Committee Chairman J. J. MacKinney was Moderator.

● This same evening your Secretary flew to Chicago. The next morning (after a delay at the Chicago airport together with Helmut Thielsch) both flew to Peoria for the First Welding Symposium of the AWS Peoria Section and Bradley University. Guy Swift was chairman of the afternoon session at which Omer Blodgett, Anthony Pandjiris and Helmut Thielsch presented three excellent technical talks. The dinner meeting was held at the unique Vonachens Junction restaurant with Chairman A. Schlis and Officers E. Savant, D. Hawes, H. D. Smith and W. Callaway in charge. Toastmaster Merle Yontz presented a bronze plaque to Elmer E. Isgren, Executive Vice-president of Le Tourneau-Westinghouse Co., to whom the entire event was dedicated. Mr. Isgren "provided a guiding hand in the formation of the AWS Peoria Section in 1938," was its first chairman, twice re-elected, always active in promoting welding and the SOCIETY.

● Your Secretary presented the main talk at the dinner meeting, discussing current activities and future plans of the SOCIETY. District Director L. L. Baugh was an active participant during both dinner and technical meetings. Following the meeting, Mr. Yontz, who is President of Le Tourneau-Westinghouse Co., conducted your Secretary on a late Saturday night inspection of the large plant and some of the huge welded earthmoving equipment constructed by his company. Several new designs were of special interest. The return trip to Stamford on Sunday was delayed by fog over New York.

● Representatives of the United States sponsor organizations—AWS, WRC and Ship Structure Committee—of the International Institute of Welding met in your Secretary's office on December 8th with Chairman Howard Biers to complete preliminary plans for the 1961 IIW Annual Assembly. AWS was represented by President C. I. MacGuffie, Vice-president R. D. Thomas, Jr., and staff members Fenton, Mooney and Plummer. On Jan. 1, 1960, Mr. Fenton will become Secretary of the American Council of IIW. Your Secretary will assume the duties of Chairman.

● F. L. Mallcott of Caracas, Venezuela, visited with your Secretary, President MacGuffie and Vice-president Thomas during this day. In the evening President MacGuffie and your Secretary joined Charles S. Burrows and Perry J. Rieppel at a dinner meeting of the New York Section to present a four-part panel discussion of "The Future of Welding." H. C. Phelps served as technical chairman and introduced the speakers except for your Secretary who was introduced by Chairman Harry Landis who dramatically recalled events during the Korean crisis which resulted in our first meeting en route to Japan on a special mission. Vice-chairman M. D. Bellware and other officers assisted at this successful meeting which was attended by Past-president O. B. J. Fraser, staff members Mooney, Phillips, Willer, Hall and Morrison, and a large group of section members.

● The following day your Secretary was pleased to greet Masao Masuda, President of Masuda Engineering Co. of Nagoya, Japan, who was interested in welding stainless steels. Mr. Masuda is a friend of Prof. H. Sekiguchi, a past president of the Japan Welding Society.

● Educational Activities Chairman

C. E. Jackson also visited headquarters this day prior to his departure for Chicago to present a talk "Technicians of Tomorrow" before a meeting of the American Vocational Association.

● Treasurer H. E. Rockefeller joined your Secretary for lunch and a conference on December 10th. Financial results for the first six months of the current fiscal year have been satisfactory, with excess of income over expense greater than estimated in the budget.

● President C. I. MacGuffie met with the Long Island Section on December 10th, providing the entire program and discussing Society development and plans. He also met with the Newark Section on December 15th, discussing progress in the fund drive for the United Engineering Center.

● On December 16th, AWS department heads and WRC Assistant Director Ken Koopman met with Architect Ficke to study partition and space layouts for the eighth floor of the new building where AWS and WRC will establish their headquarters sometime in 1961.

● During the week of January 11th your Secretary will meet with AWS Sections in Cincinnati (with President MacGuffie), Cleveland, Louisville and Columbus, and will speak before students at the University of Louisville.

● Important January meetings will include one of your Executive and Finance Committee in Philadelphia on January 18th with National Officer Night Meeting of the Philadelphia Section that evening, and one of your Technical Council in New York on January 20th.

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EDUCATIONAL ACTIVITIES

Educational Emphasis in Russia and the United States

by Clarence E. Jackson

Throughout Europe, including the USSR, there is an emphasis on technical training with instruction often channeled along limited specialties. This is contrary to much of the training in the United States which tends to be directed along a broader horizontal approach. There is also a great emphasis on the study of languages abroad as this is a requirement for the European way of life.

It is to be noted that the total enrollment in the schools in both the USSR and the United States is in the order of 30 to 40 million students. The following statistics having to do with the training of specialists may lead us to a false feeling of security as far as training in the United States is concerned:

	USSR	U. S.
Population→	208,000,000	175,000,000
Number of Specialists per 1000 Population (1955)[a]		
Professional	11.0	38.1
Scientists	5.9	9.3
Engineers	3.0	3.0
Sub-Professionals	14.9	Not available

[a] From *Soviet Economic Growth:* A comparison with the United States–Joint Committee Print–Government Printing Office 1957

However, examination of other statistics which show that the United States has a larger number of graduates of higher education also shows a lower number of engineering and scientific graduates. The following table presents the data for 1955–56:

Graduates of Higher Education	USSR	U. S.
Total	265,000	311,000
Engineering	71,000	26,000
Other Science	75,000	66,000

In the Soviet Union, efforts have been concentrated in the higher educational levels on the fields of physical and natural sciences, and engineering, rather than on liberal arts, humanities and social sciences.

Those of us who have been active in the field of welding over the past years have noted a fantastic rise in welding technology both in the United States and abroad. New processes and new techniques are being introduced at an ever increasing rate. The development of the new processes will be followed by other methods based on technology which may not exist at the present time even in the research stage. The use of new ultra-sonic, friction, electron beam or electro-slag processes are only now finding their special field of application. A new method does not replace completely an old method, but works with the existing methods and, in our growing economy, both the new and the old continue to grow. The engineer and the technician in welding—ten years hence—will undoubtedly be involved with many welding methods which do not exist today.

The use of automatic processes in welding is increasing. The approach used by the state controlled system of the USSR has been to establish by decree a performance goal of at least 50% automatic welding. This goal can be reached only by emphasizing the training of technicians. There is a reported ratio of ten welders to one engineer in the USSR. There is a probable ratio of only one engineer to 20 welders in the U. S. and it is estimated that only 20% of the welding is accomplished by automatic means.

The Educational Activities Committee recognizes a number of definite assignments: the Educational Lecture Series and the Educational Activities Seminar at the National AWS meetings. The increasing activity in the sections which present educational courses, symposiums and seminars has been an index of the growing interest in the field. The process of the preparation of text material so badly needed has continued long enough to produce tangible results. In a technical society like the AWS, which depends upon voluntary service, more workers are needed. The assistance rendered by groups, such as Government agencies, the American Vocational Association, college groups and others help to guide us in maintaining a sound AWS program.

The tremendous demand for the "Opportunities" pamphlet has proved the vitality of this type of approach and has resulted in publicizing welding in areas which have not been reached. Further distribution of this and additional booklets is essential in guiding the youth of today in a career in welding.

A program fast taking shape is the "Recommended Practices for Welding Departments in Public Schools." This presentation was originally initiated by the Detroit Section. Task forces with assignments for various sections of the outline have begun their work. This Manual will present information on opportunities, curriculum, buildings, equipment, together with sources of information. Many State Vocational educators have indicated their urgent need for such material when it becomes available.

Another project which is being planned is that of short intensive specialized courses conducted by the AMERICAN WELDING SOCIETY. This program is aimed at encouraging the most effective use of existing knowledge and promoting the use of up-to-date techniques in the welding field. These courses will be particularly useful to those who need a broader knowledge for the application of modern welding to their own operations. The first session will be held early this Spring.

The training of technicians of tomorrow must be emphasized. It is important for the welding industry to outline the needs and type of technicians which would best serve the U. S. economic system. Without sufficient training of technicians, engineers are often pressed into service as technicians. It is often necessary to use men with inadequate training as aides, and engineers in this case must spend more time on details. It is felt that today's welding and tomorrow's technology will require personnel with a broad training in order to meet the challenge which exists. An additional 100,000 technicians trained in welding will be required tomorrow.

CLARENCE E. JACKSON is chairman of AWS Educational Activities Committee.

SECTION NEWS AND EVENTS

As reported to Catherine M. O'Leary

Alabama

WELD FAILURES

Birmingham—A joint meeting of the *Birmingham* Section and the Birmingham Chapter of ASM was held on Tuesday, December 8th, at Salem's Restaurant Number Two. A large crowd heard a very interesting talk on "Why Welds Fail, Metallurgical and Physical Factors." The speaker was Helmut Thielsch, metallurgical engineer, Grinnell Co., Providence, R. I.

The talk was concerned with failures in service rather than failures immediately after fabrication. It is important that one know the causes of failures and how to avoid them, Mr. Thielsch pointed out. He also stressed the fallacies of basing design and selecting materials on laboratory test data, and assuming that fully inspected weldments are always sound. The basic causes of weld failure were reviewed in detail and numerous examples were given by the speaker.

SPEAKS ON FAILURES

Helmut Thielsch (center) spoke on the factors affecting the failure of welds at the December 8th joint meeting of AWS Birmingham Section and ASM Birmingham Chapter. R. A. Davis, AWS Section Chairman is at left; Ned Brandler, ASM Chapter Chairman is at right

POWER SOURCES

Mobile—Twenty-four members of the *Mobile* Section met on November 19th for dinner and meeting at Korbet's Restaurant.

Guest speaker was Joseph H. Wisneski, process engineer, instructor and special application engineer, affiliated with welding-machine sales for Harnischfeger Corp.

In his talk on "Power and Power Sources for Welding" he discussed the basic elements of generating electricity; methods of obtaining volt-ampere curves; transformers and rectifiers.

Arizona

MODERN WELDING PROCESSES

Phoenix—One of the largest attendances at a meeting of the *Arizona* Section took place at the October 21st dinner meeting held at the Highway House with 67 members and guests present.

C. A. Zwissler, welding engineer and A. L. Collin, manager of structural engineering at Kaiser Steel, discussed modern processes in welding as applied to welded girders, railroad components, missile work on service towers and tests stands and commercial buildings. Slides were used by the speaker to illustrate the various points of the talks.

WELDING OF STRUCTURES

Modern processes as applied to welding of structures was the topic discussed at the October 21st meeting of Arizona Section. Left to right are C. A. Zwissler, Section Chairman R. W. Sferra and A. L. Collins

HEAR TALK ON DESIGN OF WELDING EXPERIMENTS

The design of experiment applied to welding was the subject discussed by Jim Hurzeler at the November 19th meeting of the Los Angeles Section. The speaker's table and some of the other members present are shown above

Mr. Hurzeler is shown giving his recommendations on the proper organization of an experiment

SECTION MEETING CALENDAR

MARCH 1

HOUSTON Section. Welding Metallurgy Course. Session V. Chapters 10 and 11.

ST. LOUIS Section. Union Electric Co., 12th and Locust Auditorium. Educational Program, Part IV. Fluxes and Slags, Electrode Classification.

TOLEDO Section. University of Toledo. 7:30 to 9:30 p.m. Educational Clinic "Theory of Arc Welding."

WESTERN MASSACHUSETTS Section. Silhouette Restaurant, Thompsonville, Conn. Dinner 6:30 p.m. Meeting 8:00 p.m. "Inert-gas Applications" David Holster, Air Reduction Sales, Inc.

MARCH 2

OKLAHOMA CITY Section. Swyden's Restaurant. Dinner meeting. Speaker—Wayne L. Wilcox, Arcos Corp.

SUSQUEHANNA VALLEY Section. Foot Hills Manor, Schickshinny, Pa. Dinner meeting 6:45 p.m. "Welding Metallurgy," Clarence Jackson, Linde Co.

TULSA Section. Subject—"Pressure Vessels."

MARCH 3

NORTHERN NEW YORK Section. Panetta's Restaurant, Menands, N. Y. Dinner 7:00 p.m. Meeting 8:15 p.m. "Carbon-dioxide Welding," Roger Tuthill, Air Reduction Sales Co.

MARCH 4

PHILADELPHIA Section. Panel discussion. Engineers Club. Dinner 6:30 p.m. Meeting 8:00 p.m. "Design for Resistance Welding."

MARCH 7

LEHIGH VALLEY Section. Joint meeting with ASCE. Walp's Restaurant, Allentown, Pa. Dinner 6:30 p.m. Meeting 8:00 p.m. "Riveted vs. Welded Construction in Structural Steel," C. L. Kreidler, Lehigh Structural Steel Co.

MARCH 8

BIRMINGHAM Section. Salem's Number Two Restaurant. Social 6:30. Dinner 7:00. Meeting 8:00. "Fully Automatic Submerged-arc Welding," R. A. Wilson, Lincoln Electric Co.

DAYTON Section. Kuntz's Cafe. Social 6:30. Dinner 7:00. Meeting 8:00. "How and Why of Semi-conductors," J. J. Frye, Western Electric.

HOUSTON Section. Welding Metallurgy Course. Session VI. Chapter 12.

NEW YORK Section. Victor's Restaurant. Dinner 6:15. Meeting 7:15 p.m. "New Developments in Mild-steel Electrodes," A. W. Zeuthen, Socony Mobil Oil Co.

NORTHEAST TENNESSEE Section. "Field Erection of Containment Vessels for Nuclear Reactors."

SAGINAW VALLEY Section. Joint meeting with Valley Section A.S.M. "Brazing and Soldering," D. C. Herrschaft, Handy & Harman.

ST. LOUIS Section. Union Electric Co., 12th & Locust Auditorium. Educational Program, Part V. "Difficulties and Defects, Welding Common Steels, Welding Economics."

TOLEDO Section. University of Toledo. 7:30 to 9:30 p.m. Educational Clinic, "Theory of Arc Welding."

MARCH 9

PASCAGOULA Section. Holiday Inn, Pascagoula, Miss. "Welding of High Yield-strength Steels," D. J. Snyder and J. M. Trutz, United States Steel Corp.

STARK CENTRAL Section. American Legion Hall, Canton, Ohio. Speaker—William Coughlin, Arcair Corp.

MARCH 10

IOWA-ILLINOIS Section. LeClaire Hotel, Moline, Ill. "Design of Weldments Incorporating Steel Castings," George K. Dreher, Birdsboro Steel Foundry & Machine Co.

J. A. K. Section. Kankakee, Ill. "Gas Tungsten-arc Welding," H. S. Davis, Airco.

ST. LOUIS Section. Ruggeri's Restaurant. "New Developments in Welding Thin Metals," H. L. Meredith, Airline Welding & Engineering Co.

MARCH 11

DETROIT Section.

MARCH 14

NORTHWEST Section. Elks Club, Minneapolis, Minn. Happy Half Hour 6:00. Dinner 6:30. "Power Sources for Welding," Warren Sykes.

WICHITA Section. "All's Well That Ends Welded," A. K. Pandjiris, Pandjiris Equipment Co.

MARCH 15

HARTFORD SECTION. "Pipe Welding."

HOLSTON VALLEY Section. Johnson City, Tenn. "New Applications of Submerged-arc Welding," W. B. Sharav, Linde Co.

HOUSTON Section. Welding Metallurgy Course. Session VII. Chapter 13.

NEW HAMPSHIRE Section. Queen City Motel, Manchester. 7:00 p.m.

NEW JERSEY Section. Essex House, Newark. Dinner 6:30. Meeting 8:00 p.m. "A Talk About Welding Technicians," Howard B. Cary, Hobart Bros. Technical School.

OLEAN-BRADFORD Section. The Castle, Olean, N. Y. Dinner 7:00 p.m. Meeting 8:30 p.m. Speaker—Jules Cruchet, Ford Motor Co.

TOLEDO Section. "University of Toledo. 7:30 to 9:30 p.m. Educational Clinic "Theory of Arc Welding."

YORK-CENTRAL PENNSYLVANIA Section.

MARCH 16

PITTSBURGH Section. Auditorium, Mellon Institute. "Metal Cladding and Maintenance Welding," R. L. Rectenwald, Maintenance Engineering Corp.

MARCH 17

DETROIT Section. "Multiple-operator Power Source."

WASHINGTON Section.

MADISON Section. Beloit, Wisc. Compressed-air Carbon-arc Process," Myron D. Stepath, Arcair Co.

JOHNSTOWN Sub-Section (Pittsburgh Section) V.F.W. Post 155, Johnstown, Pa. "Safety in Welding," H. W. Speicher, Westinghouse Electric Corp.

MARCH 18

CHICAGO Section. Milner's Restaurant, Dinner 5:45 p.m. Peoples Gas Auditorium, Meeting 7:30. "Welding Heavy Sections," E. C. Chapman, Combustion Engineering Corp.

FOX VALLEY Section. Plant tour and dinner.

MARYLAND Section. Engineers Club, Baltimore. "Brazing Challenges the Thermal Barrier," D. C. Herrschaft, Handy & Harman.

MILWAUKEE Section. Ambassador Hotel. "Performance of Welds in Aluminum Alloys," Paul B. Dickerson, Aluminum Company of America.

PEORIA Section. Vonachen's Junction. Dinner 6:30 p.m. Annual Business Meeting.

MARCH 21

PHILADELPHIA Section. Engineers Club. "Machinery for Automatic Welding," H. J. Lange, National Electric Welding Machines Co.

ROCHESTER Section. Rochester, N. Y. "The Control of Resistance Welding," Glenn B. Heck, Weltronic Company.

MARCH 22

HOUSTON Section. Welding Metallurgy Course. Session VIII. Chapters 14 and 15.

LOUISVILLE Section. Plant tour of General Electric Co., Appliance Park.

TOLEDO Section. University of Toledo. 7:30 to 9:30 p.m. Educational Clinic "Theory of Arc Welding."

MARCH 24

NIAGARA FRONTIER Section. LaSalle Yacht Club, Niagara Falls, N. Y. Dinner 6:45 p.m. Meeting 8:15 p.m. "Maintenance and Shop Welding," George Hirsch, Plantec Corp.

MARCH 25

INDIANA Section. Dinner—Mural Room, Millers Restaurant. Meeting—State Teachers Building, Indianapolis. "It Isn't Mud," Harry R. Reid, Jr., McKay Co.

MARCH 28

SAN FRANCISCO Section. Dinner meeting. "Why Welds Fail," Helmut Thielsch, Grinnell Co.

Editor's Note: Notices for May 1960 meetings must reach JOURNAL office prior to February 20th, so that they may be published in the April Calendar. Give full information concerning time, place, topic and speaker for each meeting.

APRIL IS NATIONAL WELDED PRODUCTS MONTH

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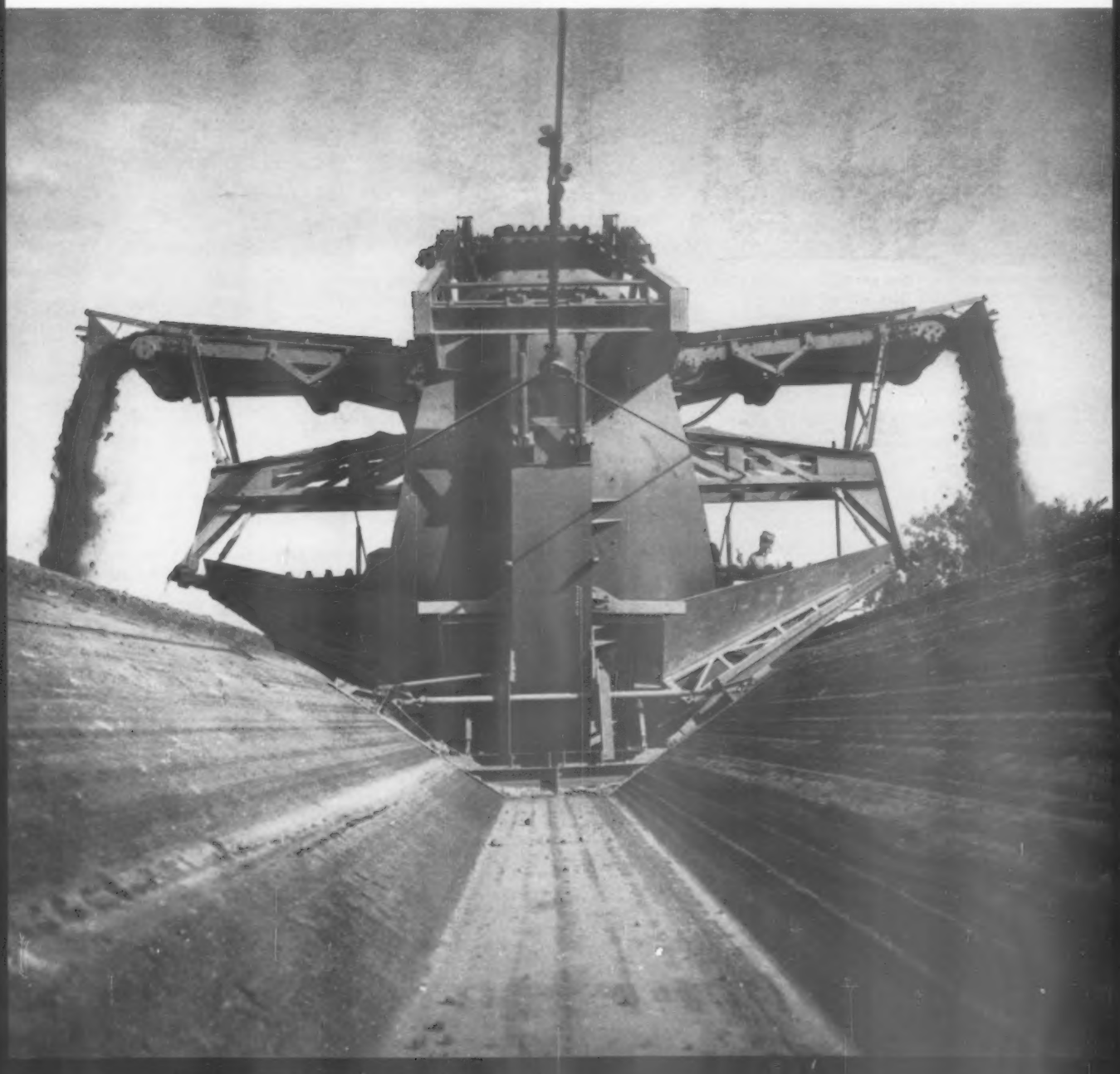
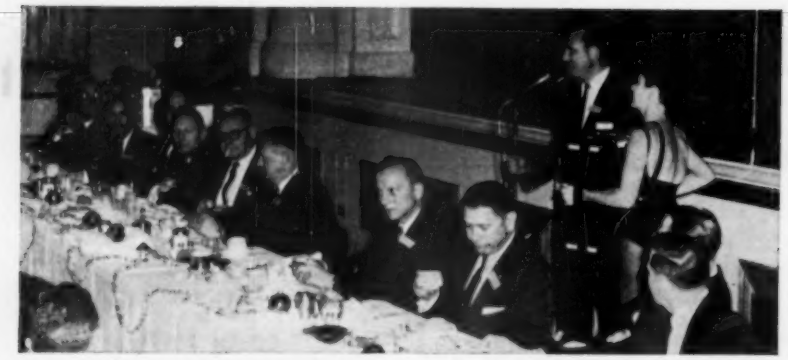


LOS ANGELES HOLDS CHRISTMAS PARTY



Officers of the Los Angeles Section, seated at the head table, enjoy the singing of Mike Kensrue and the accordion playing of Ann Mills at the Christmas Party held on December 4th

One of the fine entertainers who performed for those present was Jacqueline Hurley

Enjoying the festivities are (left to right) L. Sommer, Al Toler, F. J. Collo, H. L. Meredith, Ed Harwart and Carl Sense

Shown deep in conversation are (left to right) R. McGhee, G. Stukkie, Joe Cye, C. Carney, R. Parrot, H. Denhart, C. Johnson and K. King

California

DESIGN OF EXPERIMENT

Los Angeles—The November 19th meeting of the *Los Angeles* Section featured Jim Hurzeler, welding laboratory supervisor for North American Aviation Co., as guest speaker. Mr. Hurzeler's subject "Design of Experiment Applied to Welding" was intended to interest people in the use of the properly "designed" welding experiment. Welding experimenters usually being so engrossed in the volume of actual work that shorter or more effective methods of experiment are seldom considered. Examples were shown to acquaint or remind welding engineers of the proper organization of an experiment and the various designs which an experiment can take. The presentation was well supported with slides and was enjoyed by an audience of approximately 75 members and guests.

A film in color, entitled "Nike Hercules Tooling" concluded the evening's program, which was highly enjoyed by all those in attendance.

CHRISTMAS PARTY

Los Angeles—The *Los Angeles* Section held their annual Christmas party on Friday evening, December 4th, at the Rodger Young Auditorium with 186 members and guests in attendance. Responsible for the procurement of the talented group of performers was "Mac" McGinley, 10th District Director and past chairman of the Section. Some of the acts included audience participation which always goes over big at these parties.

The social hour started at 6:00 p.m. This was followed by a superb dinner at seven.

During the dinner hour, Section Chairman Dick Hayes introduced the officers and prominent guests. Then, without any further formalities, he introduced Vice-chairman John Wiley who presented the bill of entertainment for the evening. This was a great show and was concluded by the drawing of many wonderful door prizes. The latter feature was handled by Al Fenalson, membership chairman for the Section.

A wonderful party, a great night, and a grand time was had by all.

ELECTRON-BEAM WELDING

San Diego—A dinner meeting of the *San Diego* Section was held November 18th in the Don Room of the El Cortez Hotel.

Program Chairman Roger Beemer presented the guest speaker, H. O. Klinke, Eastern Division Representative of Air Reduction Co. Mr. Klinke gave an interesting talk on "Electron-beam Welding." His presentation covered the development of this process, the present state of the art and included suggested future usage. Following his talk, there was a question-and-answer period which was participated in by all of the members.

For details, circle No. 11 on Reader Information Card →

World's biggest submarine welded with M&T Murex ELECTRODES

The U.S.S. Triton—launched in May 1958, commissioned in November 1959—can travel completely submerged for more than two months with a crew of 148. This atom-powered giant, built by the Electric Boat Division of General Dynamics Corp., is three times heavier and 40% longer than conventional World War II subs. Construction consumed some 200,000 pounds of Murex electrodes – products of METAL & THERMIT CORPORATION, General Offices: Rahway, N. J.

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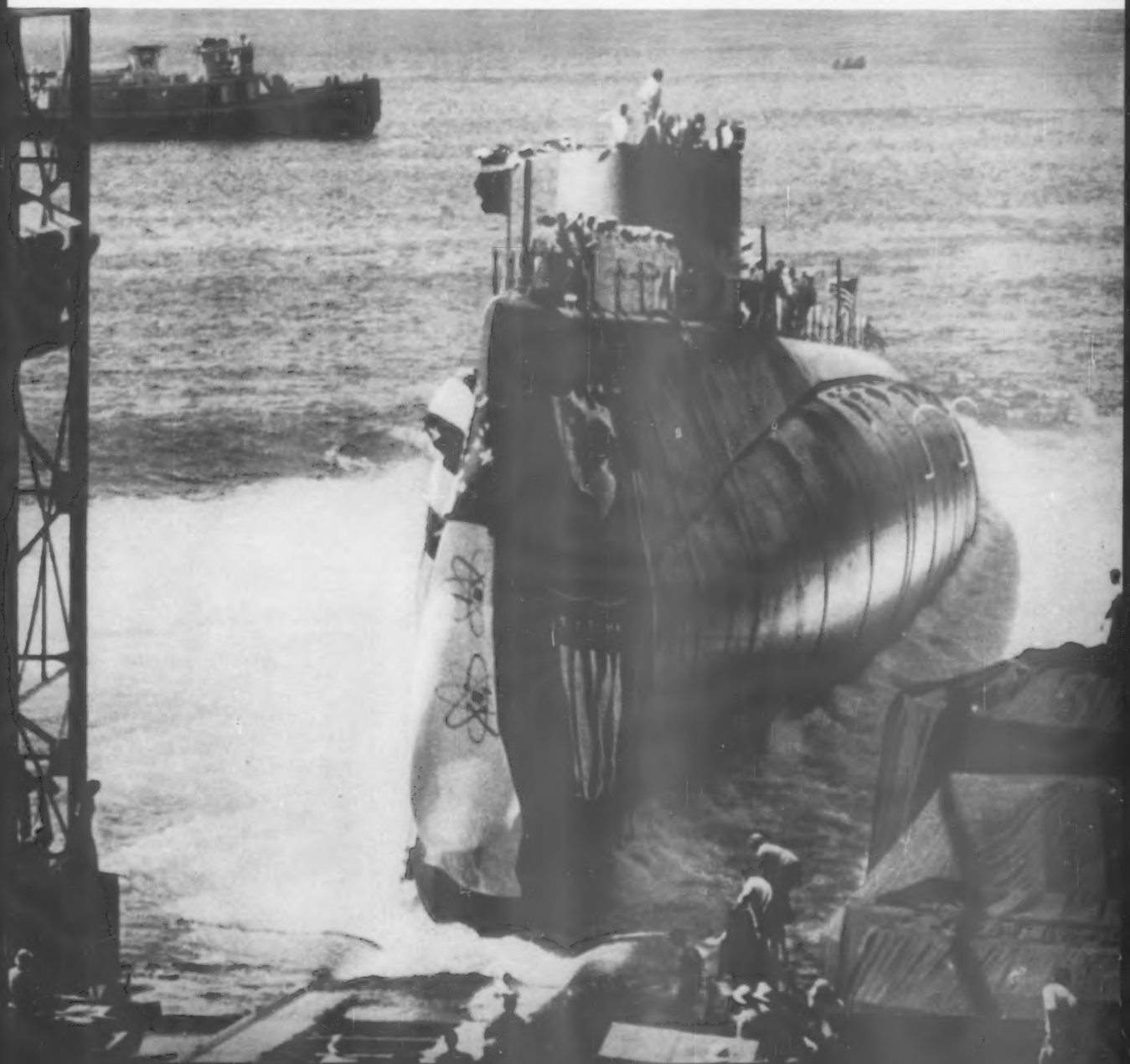

GAS METAL-ARC WELDING IS THE SUBJECT

Seated at the speakers' table at the November 23rd meeting of San Francisco Section are (left to right) W. F. Ajello, B. F. Faas, Guest Speaker R. W. Tuthill, Section Chairman R. E. McCormick, K. C. Cummings, J. Basich and District Director C. B. Robinson

This is a part of the many members and guests present to hear Mr. Tuthill's presentation on the application of the inert-gas-shielded metal-arc welding process

INERT-GAS WELDING

Berkeley—On Monday evening, November 23rd, the *San Francisco* Section met for dinner and regular meeting at Spengers Fish Grotto in Berkeley.

Technical speaker was R. W. Tuthill, assistant manager, development department of Air Reduction Sales Co., Union, N. J. His subject was "Metal Inert-Gas Welding." Among many items discussed were power sources used for subject process. These were machines capable of producing voltages of three types: drooping, rising and flat. This process also features three types of arc transfer: "spray," that type normally associated with general welding; "globular," that type desired where a minimum of dilution with the base material is required; and the third, "dip transfer", the latest development, is generally associated with small diameter electrodes (0.035 in.) for nonpositioned work.

Mr. Tuthill presented slides showing various types of filler metals as well as some unusual appearing welds made in the vertical position. Also shown were some high-speed motion-picture film showing close-ups of arc transfer with the various types of arc transfer. These high-speed photos offered a good study of arc action. Also noted were the effect of various gases as well as combination of gases.

Not only did Mr. Tuthill present the subject very well, but he created much interest which resulted in a good question-and-answer period.

Well selected demonstrations and stories of an entertaining nature were well received, making for a well-rounded program for the evening.

CARBON-DIOXIDE WELDING

Palo Alto—Sixty-five members and guests of the *Santa Clara Valley* Section were present on November 24th for dinner at Hal's in Palo Alto and these were joined by five more at the meeting which followed.

A very informative lecture on "Dip-transfer Carbon-dioxide Welding" was given by R. W. Tuthill, assistant manager, Development Department, Air Reduction Sales Co., Union, N. J. He explained the significance of the dynamic characteristics of new power supply and its effects on results in low-current CO_2-gas-shielded consumable-electrode welding.

Mr. Tuthill was most entertaining with his humorous stories and revolutionary device for making "fast-bucks."

AIR LINES TOUR

San Francisco—One hundred and eight *Santa Clara Valley* Section members, their wives and teen-age children enjoyed an extensive tour of the United Air Lines Maintenance Base at the International Airport in San Francisco on the evening of December 15th. United Air Lines representatives met the members at the main gate and directed them to gather in the beautiful main lobby. They were then conducted

CO_2 WELDING IS TOPIC IN SAN JOSE

R. W. Tuthill spoke on the carbon-dioxide welding of steel at the November 24th meeting of Santa Clara Valley Section. At speaker's table are (left to right) District Director C. Robinson, Section Chairman Ron Skow, Mr. Tuthill, W. R. Smith and F. D. Nelson

Dick Belding (right) was congratulated and presented with certificate of commendation by Chairman Skow for fine membership job in 1958–59

For details, circle No. 12 on Reader Information Card →

World's toughest test withstood by M&T Murex ELECTRODES

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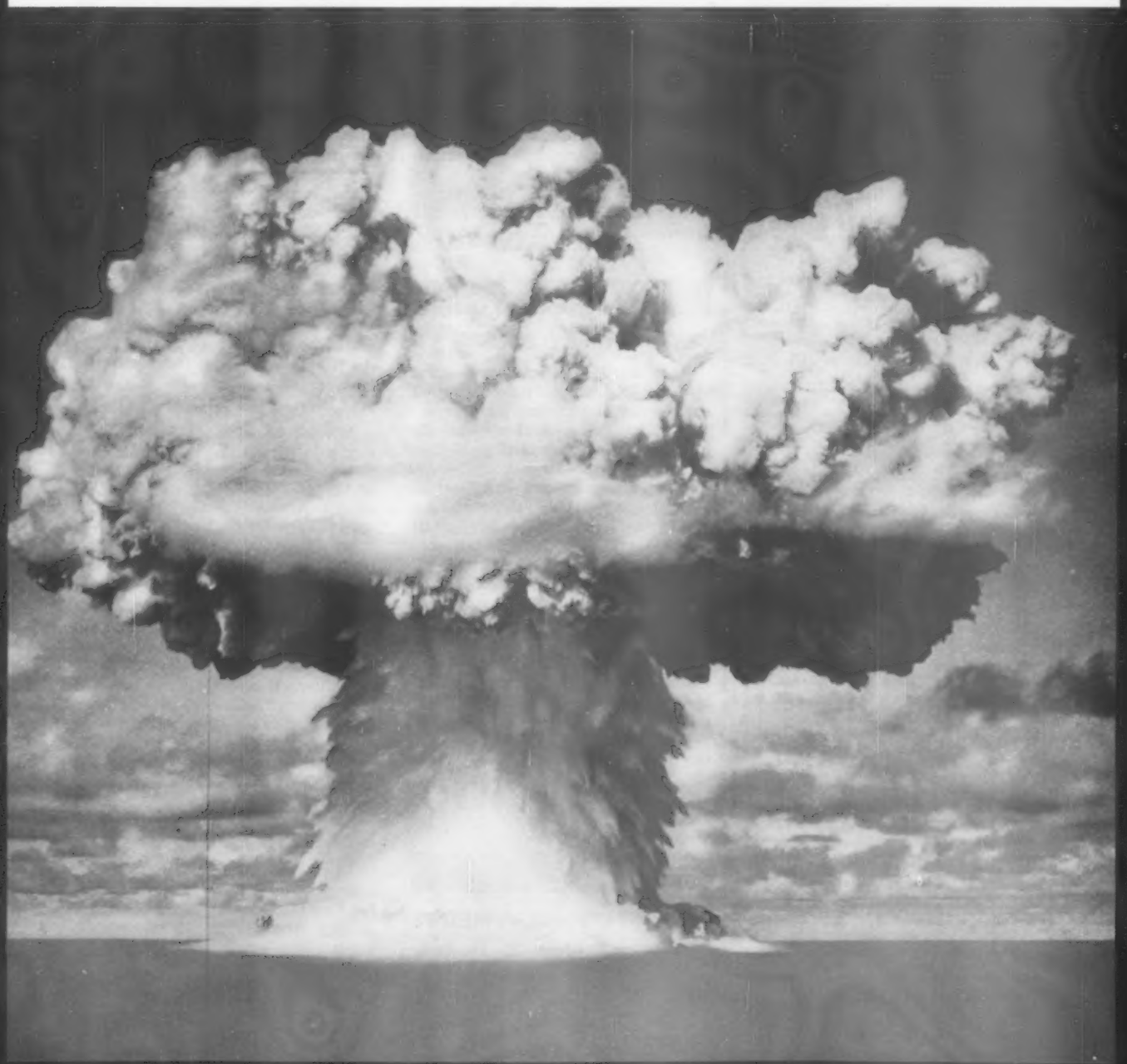
PRODUCTS FOR BETTER WELDING



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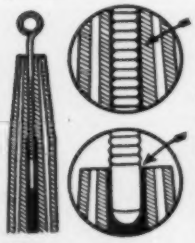
The exclusive circle design found only in Wypo Cutting and Welding Tip Cleaners provides as many as 60 more cleaning edges per inch of cleaner.



These rounded outer edges of cleaning ridges clean and polish tip orifice without scratching or cutting.

This smooth pilot guides WYPO Tip Cleaner into tip Will not enlarge or damage tip port.

This cross section view of WYPO Cleaning Surfaces shows these exclusive features:

Rounded cleaning surfaces that won't jam or cut.

Straight sided valleys insure thoro cleaning by removing all waste.

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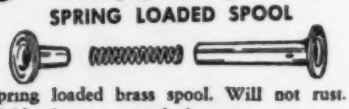

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Insures longer life for small sizes of WYPO Tip Cleaners. Will not pull out of case.

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CLEANER NO.	FOR DRILL
7	75-74
8	73-72-71
10	70-69-68
12	67-66-65
14	64-63-62
15	61-60
16	59-58
17	57
18	56
22	55-54
24	53-52
26	51-50 49

MADE IN U.S.A.
PAT NOS 2439381, 2472708 (in Canada 1960)

STANDARD SET OF (12) Cleans (27) Drill Sizes Nos. 75 to 49 Incl.

WYPO TIP CLEANERS JUMBO SET

CLEANER NO.	FOR DRILL
28	48-47
30	46-45
32	44-42
34	42-41
37	40-39-38
39	37-36
42	35-34-33
44	33-31
45	30

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CLEANER NO.	FOR DRILL
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12	67-66-65
14	64-63-62
15	61-60
16	59-58
17	57
18	56
22	55-54
24	53-52
26	51-50-49
28	48-47
30	46-45
32	44-43
34	42-41
37	40-39-38
39	37-36
42	35-34-33
44	33-31
45	30

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to the fine cafeteria for an appetizing dinner of roast beef.

Chet Wiggens extended the hospitality of United to the visiting guests and introduced the seven guides who were to conduct the tour of the Base. Mr. Wiggens discussed the importance of the Base as the major overhaul locale for all their operations. He also noted how its location in the San Francisco area materially affected the economy of the Bay Area.

The Base tour consisted of an extensive visit through the Engineering and Maintenance Base Headquarters offices, all the facilities of the machine and engine-repair overhaul shops, sheet metal, welding, and heat-treat shops, the instrument overhaul and testing area, the jet maintenance and testing area, and the upholstery manufacturing and sewing departments.

The new maintenance area for the DC-8 Jets was inspected and an opportunity was afforded to watch a DC-8 Jet Mainliner being tested and readied for flight in the outside test area.

The United Air Lines representatives were most cordial and informative throughout the tour. All the members who attended were grateful for the opportunity to visit the Maintenance Base.

Colorado

CENTURY OF WELDING

Denver—The *Colorado* Section held its December 8th meeting at Cavaleri's Restaurant in Denver. The group gathered at about 6:30 p.m. for an appetizer until 7:00 p.m. when dinner was served.

The meeting opened at 8:00 p.m. with a talk by Harry Schwartzbart of Armour Research Foundation of Chicago. The topic of his talk was "One Hundred Years of Welding." He told of the first welding of ships, bridges, pipes and airplanes; also of brazing, ultrasonic welding, high-frequency resistance welding, two types of plasma-jet torches, friction welding and electroslag welding. He used slides to illustrate his talk; all of which was very interesting.

Coffee speaker was Capt. Herman Ordblom of the Denver Fire Prevention Bureau, who spoke on "Related Hazards to the Steel Fabrication Industry."

Connecticut

WELDING DISSIMILAR METALS

Bridgeport—John F. Donnelly of All-State Welding Alloys, Inc., White Plains, N. Y., was the speaker at the November 19th dinner meeting of the *Bridgeport* Section held at the Fairway Restaurant.

Mr. Donnelly spoke on welding of dissimilar metals, principally aluminum to copper. He told of the new alloys and fluxes that have been developed for this application. He also spoke on a new low-temperature solder which is used primarily for containers in the food industry.

Florida

WELDED STRUCTURAL CONNECTIONS

Miami—Heavy showers and hazardous driving conditions did not dampen the spirits of 67 members and guests of the *South Florida* Section from attending the third regular monthly meeting of the year held on November 18th at the Pioneer Club. H. J. Ross of H. F. Ross & Associates, prominent consulting engineer, was the principal guest speaker for the evening.

Program Chairman Harold Hose, in introducing Mr. Ross, gave a short résumé of his background. "Structural Welded Connections, with Reasons for Various Designs and Type and Size Welds" was Mr. Ross's subject for the evening. Many phases of structural designs and welded connections were highlighted.

WELDING FOR ATOMIC POWER

Miami—The *South Florida* Section held its fourth regular monthly meeting of the year on Wednesday night, December 16th at the Pioneer Club. Robert Armstrong, chief metallurgist at the USI Technical Center, Inc., Pompano Beach, Fla., was the principal speaker.

Mr. Armstrong gave a very interesting talk on the nuclear power plant located at Dresden, Ill. Slides that covered many phases of the project were shown which included erection, welding procedures and nondestructive testing methods used throughout the project.

Illinois

CHRISTMAS PARTY

Chicago—The 5th Annual *Chicago* Section Christmas Party was held on December 11th at the Martinique Restaurant in Evergreen Park. The affair was attended by

SECRETARY ADDRESSES ASME STUDENT CHAPTER

H. Green, T. Provencher, G. Thielen, J. Hollingsworth and D. Filomeno are the officers who presided at recent meeting of the ASME Student Chapter of Illinois Institute of Technology, when Secretary Fred L. Plummer discussed welded fabrication and opportunities in the welding industry

115 couples, a complete sellout. The evening's entertainment included corsages for the ladies, cocktails, dinner, dancing to a name band and a drawing for door prizes. The evening was a tremendous success.

SELECTION OF ELECTRODES

Aurora—A very fine discussion on "Selection of Electrodes" accompanied by slides, and a discussion of low-hydrogen electrodes versus 6010 electrodes, was given by Jerry Hinkel of the Lincoln Electric Co., Cleveland, Ohio, at the November 12th meeting of the *J.A.K.* Section held at Harmony House in Aurora.

WELDING T-1 STEELS

Peoria—The *Peoria* Section held its regular monthly meeting at Vonachen's on Wednesday, Nov. 18, 1959. The speaker, Louis K. Keay, manager of the Technical Service Dept., Lukens Steel Co., covered very well the subject "Fabrication and Welding of T-1 Steels." His discussion was educational and of interest to people from management to shop operators. A dinner preceded the meeting.

Indiana

RESISTANCE-WELDING APPLICATIONS

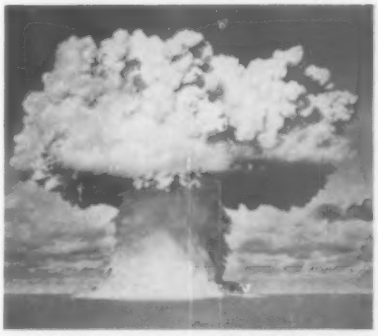
Cumberland—The November meeting of the *Indiana* Section was held one week earlier due to the Thanksgiving holiday. It was held at Buckley's Restaurant in Cumberland on November 20th.

John D. Eyestone, senior engineering department of Western Electric, Hawthorne Works, Chicago, Ill., was the speaker. His talk on "Resistance-Welding Applications at Western Electric, Hawthorne Works" was accompanied by slides and samples of welded assemblies.

PLAY HOSTS TO NATIONAL OFFICERS

President C. I. MacGuffie and Secretary Fred L. Plummer spoke at the November 12th meeting of Iowa-Illinois Section. They are shown above with some of the Section officers present (left to right): V. Long, A. Dailey, G. Zippay, President MacGuffie, D. Hunt, R. Custer, L. Palmer and Secretary Plummer

Fastest Ditcher



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PLANT TOUR

Indianapolis—A plant tour of the U. S. Naval Avionics Facility by 64 members of the *Indiana* Section started at 5:30 p.m. followed by dinner in the plant cafeteria on December 18th.

At the close of the dinner, Commander G. R. Fraser made a welcoming address on behalf of Capt. B. Day who could not be present. This was followed by an explanation of the function of the facility, including past experience with the manufacture of Norden Bomb Sights and Fire Control equipment of optical and mechanical design, now replaced by Radar, control for guidance. While this is a Navy Facility (under Bureau of Weapons), they also develop and produce some projects for the Army and Air Force. The Facility employs 2500 and has a staff of 12 military personnel, consisting of eight officers and four enlisted men. T. E. Woodruff who has charge of sheet-metal fabrication and production welding answered questions pertaining to the work that was being done.

WELDING EDUCATION

South Bend—The *Michiana* Section started their new year with a discussion of operator and engineer education methods by A. N. Kugler, chief welding engineer, Market Development Section of Air Reduction Sales Co., New York. This talk turned out to be a very nice combination of technical discussion and travel lecture, due to the fact that a main part of Mr. Kugler's presentation was the showing of slides taken during his attendance at the International Institute of Welding meeting held in Essen, Germany, in 1957. The audience was introduced by these pictures to some interesting European welding applications, as well as to the West German Welding Show. This show, in a country with an area about the same as New York and Pennsylvania, is said to be much larger than anything put on in the United States. Most interesting was a visit to one of the German Welding Society's centers for instruction. Here, special welding training can be obtained for anything from operator to welding engineer.

The above meeting was held on September 17th at Russ Restaurant in South Bend.

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HIGH-TEMPERATURE CORROSION

South Bend—The November meeting of the *Michiana* Section was devoted to a subject perhaps a little afield from welding and, yet, not without its practical side for the welder. On the 19th, John Schley of the Haynes-Stellite Division, Union Carbide & Carbon Co., Kokomo, Ind., gave a very interesting discussion of the nature and problems of high-temperature corrosion. While ordinary corrosion at room temperatures will not take place if the environment has a humidity of less than 40%, at elevated temperatures even the driest atmosphere will corrode, if a corroding element is present. These elements include oxygen, sulfur, carbon, vanadium, boron, and even aluminum, copper and zinc if they are molten. Different metals corrode at different rates, mainly due to degree of protection which the layer of corrosion product first formed gives to further action of the corrodent. Unfortunately our best refractory metals, molybdenum, tungsten, etc., oxidize very rapidly at the temperatures where only they have any degree of strength.

Welding slag insufficiently removed can be a source of devastating corrosion at temperatures around 2000° F, as can contact with refractory materials such as SiO_2 and Al_2O_3. One company found to its sorrow that a detergent used to test a vessel for leaks could cause rapid deterioration in areas from which it was not removed. The role of welding slag to pick up sulfur from a low-sulfur atmosphere and concentrate it until it becomes an active corrodent was presented. The penetrating powers of molten metals, such as brazing alloys, applied to metals under stress was pointed out. While high-temperature corrosion seems to be a subject of little interest to welders, this discussion showed the responsibility which the welder has to eliminate premature failure due to improper welding operations.

Louisiana

INERT-GAS WELDING

New Orleans—Thirty-nine members of the *New Orleans* Section gathered at Caruso's Continental Room on November 17th for the monthly dinner and meeting.

Speaker at the meeting was H. D. Mann of the Air Reduction Sales

ANALYZES FAILURE OF WELDS

The reasons as to why some welds fail were explained by Helmut Thielsch in his talk before the Worcester Section on November 9th. These are some of the members and guests present at dinner preceding meeting

Co., New York, who gave a most interesting and enlightening talk on "Inert-Gas Welding." In addition to this talk, Mr. Mann showed some very interesting slides and high-speed films.

Maryland

HIGH-TEMPERATURE BRAZING

Baltimore—The regular monthly meeting of the *Maryland* Section was held on November 20th at the Engineers Club in Baltimore. The dinner speaker was Robert L. Leaverton, assistant superintendent of the Baltimore City Water System. Mr. Leaverton showed a film which went back to the very beginning of the city water supply, the pump, and then up from the first real system taking water from Jones Falls through the Lock Raven and the Liberty Dam Systems to the expected use of water from the Susquehanna within a few years. He also told about the problems and accomplishments of his department in relation to purification and distribution of water.

The technical speaker was Peter Patriarca, metallurgist at the Oak Ridge National Laboratory. The subject of his talk was "High-temperature Brazing for Nuclear Reactors."

Mr. Patriarca described the basic reactor systems and pointed out system components in which brazing problems occur. The importance of considering brazing-alloy composition, mechanical properties, brazing temperature and capture cross section in alloy selection was discussed. The need for low-dewpoint hydrogen as a furnace atmosphere in brazing corrosion-resistant alloys was shown by considering the metal-metal oxide equilibrium in an H_2 atmosphere.

The importance of environmental corrosion resistance of brazed joints was emphasized, and procedures were described for corrosion testing a brazing alloy. Several interest-

WELDING OF NICKEL ALLOYS EXPLAINED

The fusion welding of nickel-containing alloys was explained by L. M. Petryck at the December 14th meeting of Worcester Section. Left to right (above) are K. Clarke, U.S.N. Charanchini, Mr. Petryck, Section Chairman Ed Hall, E. Spellman and J. Belisle

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MacGUFFIE AND PLUMMER VISIT ST. LOUIS

Chairman H. W. Castle, Secretary Fred L. Plummer, President C. I. MacGuffie and Vice-Chairman Ned Nyberg are shown at the October 15th meeting of St. Louis Section. Mr. MacGuffie and Mr. Plummer were the principal speakers

ing photomicrographs were projected showing the reaction of various acceptable and unacceptable brazing-alloy compositions to the corrosive environments air, water, liquid sodium and molten fluorides. Of particular interest was the illustration of the selective removal of boron and silicon from a Ni-Si-B alloy on exposure to molten fluoride salt, liquid soldium and still air at 1500° F.

The remainder of the talk concerned brazing and welding methods applied in fabrication of particular reactor-system components. Excellent illustrations were provided by a series of slides.

Mr. Patriarca illustrated the fabrication of a typical fuel element by showing a color movie with sound entitled "Fabrication of Fuel Elements for the Geneva Reactor."

Massachusetts

WHY WELDS FAIL

Worcester—Forty-one members and guests of the *Worcester* Section met on November 9th at Nick's Grill for a dinner and technical meeting. Chairman Ed Hall presided as program co-chairman, and Joe Belisle introduced Helmut Thielsch of the Grinnell Co., Providence, R. I.

Mr. Thielsch's topic was "Why Welds Fail." The welding and methods of inspection used on high-pressure work were discussed. Making use of slides, Mr. Thielsch presented a fine talk, and a brisk question period followed.

A film on "Wild Life in the Rockies" was shown prior to the technical meeting.

WELDING OF NICKEL ALLOYS

Worcester—The *Worcester* Section met on December 14th at Nick's Grill for dinner and meeting. A color motion picture on the mining of nickel was shown. This was of particular interest as the speaker for the evening was L. M. Petryck of the International Nickel Co. Inc. Mr. Petryck covered the weldability of nickel containing alloys. His talk was accompanied by slides.

New Jersey

RESISTANCE WELDING

Newark—"What About Resistance Welding?" was the subject of Warren F. Savage of Rensselaer Polytechnic Institute at the monthly meeting of the *New Jersey* Section held at the Essex House in Newark on November 17th.

The 65 members and guests present had the privilege of a visit by President Charles I. MacGuffie, who gave a brief talk at the opening of the meeting on the new 18-story United Engineering Center now under construction in New York City.

In an interesting, well-illustrated discussion following President MacGuffie's talk, Dr. Savage summarized various applications of fusion welding that are adaptable to resistance-welding methods, and described the basic design considerations involved in the application of resistance welding. The types of joints—spot and seam—were discussed, as well as the features of flash and butt welding, including the newly developed magna-flash tech-

NEW JERSEY SECTION SPEAKERS

President C. I. MacGuffie addressing the November 17th meeting of New Jersey Section. He spoke on the new United Engineering Center

Warren F. Savage was the technical speaker. His topic dealt with various phases of resistance welding

nique. The speaker also described the foil-butt-seam resistance-welding method.

A lively question and answer session followed the talk, and during the refreshment period after the meeting, many gathered around the display of various types of resistance welds to learn more about this method of joining.

New York

MEMBERSHIP NIGHT

Farmingdale—President MacGuffie provided the serious side of the Annual Membership Night meeting of the *Long Island* Section held on December 10th at the Casa Lou Restaurant in Farmingdale.

Mr. MacGuffie's presentation covered the aims and purposes of the SOCIETY and its place in in-

WELDING EDUCATIONAL SEMINAR

March 16–17, 1960

Essex House, Newark, N. J.

Sponsored by AWS New Jersey Section

Fourteen topics covering five areas of welding will be discussed, and visits to welding research laboratories and fabricators in the area are scheduled for Thursday morning, March 17th.

Speakers and their topics are as follows:

Wednesday, March 16

Morning Session	QUALITY CONTROL IN WELDING
9:00 to 11:30 a.m.	Destructive Testing Clarence E. Jackson, Linde Co. Nondestructive Testing Glenn Gibson, Carpenter Steel Co. Practical Applications of Quality Control Stanley Roberts, Portsmouth Naval Shipyard
Lunch—11:45 a.m. to 12:45 p.m.	
Afternoon Session	RECENT ADVANCES IN WELDING
1:00 to 5:15 p.m.	Adhesive Bonding E. Bober, Westinghouse Corp. Ultrasonic Welding and Soldering W. Potthoff, Aeroprojects, Inc. Arc-spot Welding Panel Discussion CO_2 and CO_2 Mixtures Panel Discussion
Dinner—5:30 to 6:45 p.m.	
Evening Session	BIG AND LITTLE IN WELDING
7:00 to 8:40 p.m.	Problems of Miniaturization I. S. Goodman, Westinghouse Corp. Welding Massive Sections W. Apblett, Foster Wheeler Corp.
Coffee break 8:40 to 8:55 p.m.	
Question - and - answer period 8:55 to 10:00 p.m.	

Thursday, March 17

Morning Session	CHOICE OF FOUR PLANT TOURS
9:00 a.m. to 12:30	Linde Co., Development Laboratory Air Reduction Co., Central Research Labs. General Motors Corp., N. J. Assembly Plant Magor Car Corp.
Lunch 12:45 to 1:45 p.m.	
Afternoon Session	MECHANIZATION AND AUTOMATION IN WELDING
2:00 to 5:00 p.m.	Arc Welding and Cutting J. Berryman, Air Reduction Co. Resistance Welding J. Cooper, Taylor-Winfield Corp. Soldering and Brazing A. Setapen, Handy and Harman
Dinner 5:15 to 6:30 p.m.	
Evening Session	CODES, STANDARDS AND WELDER QUALIFICATION
6:45 to 8:45 p.m.	Codes and Standards A. N. Kugler, Air Reduction Co. Welder Qualification N. Schreiner, Linde Co.

The intended purpose of the two-day seminar is to provide up-to-date information on welding and joining methods, and weld testing and quality control for the welder, welding technician, welding supervisor and foreman, and to serve as a refresher for the production and design engineer.

Registration fee of $20 includes lunch and dinner for both days and plant tour; optional registration fee of $10 includes plant tour, without meals.

To register, mail your check to: AMERICAN WELDING SOCIETY, c/o C. J. Sullivan, P. O. Box 2, Union, N. J.

HEAR PRESIDENT

President C. I. MacGuffie is shown addressing the Membership Night meeting of Long Island Section on December 10th. To his right are R. Noble and E. Mitchell

dustry; past, present and future.

The responsibility of individual members for furthering interest in welding at local educational levels was also covered. He concluded with a description of the staff and facilities to be made available at the new headquarters.

FUTURE OF WELDING

New York—A panel discussion of "The Future of Welding" brought 85 members and guests to the December 8th meeting of the *New York* Section.

Four experts in the welding field participated in the program. They were national president C. I. MacGuffie; Chas. S. Burrows of the Martin Co.; Perry Rieppel of Battelle Memorial Institute; and National Secretary Fred L. Plummer.

As usual, the meeting was held in Victor's Restaurant at 1 E. 35th St. The formal program was preceded by a social get-together and a fine steak dinner. Bill Hall was the lucky winner of the door prize for the evening. New member Fred Kelly was introduced to the meeting by Chairman Harry Landis.

H. C. Phelps, the toastmaster for the evening, introduced President MacGuffie, who started off the discussion of "Welding in the Future."

Mr. MacGuffie described two welding tools of the future, which are now in the laboratory-development stage, but which may be the answer to how to weld the "space age" materials.

He described both electron-beam welding and the plasma-jet welding process as newly developed versions of processes embodying old basic principles.

Mr. MacGuffie pointed out the advantages of the electron-beam process as: minimum weld contamination (due to both the cleaning action of the beam and the hard vacuum atmosphere the process operates in); position and size of weld pool can be accurately controlled; excellent utilization of arc power and the fact that it could be used in outer space in the future.

The plasma jet, which is a neutral flame of extremely high temperatures (between 10,000° and 22,000° F), is an excellent source of heat for cutting and spraying. The extreme heat of the plasma jet can cut tungsten and ceramics. It can be used to spray ceramics and high-melting metals.

Mr. MacGuffie concluded by saying that these processes, so far in laboratory work, seem to satisfy many of the requirements for joining and cutting the materials of the future and therefore should be looked at as the welding tools of the

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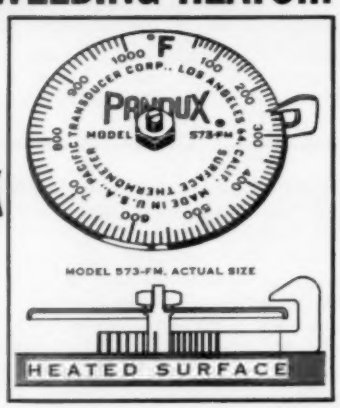

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future.

Charles S. Burrows, group engineer, Missiles and Electronics Division, The Martin Co., was the second speaker. He is in close contact with the leading space development programs in the U.S.A. He discussed welding as it will be applied to the space vehicles of the future.

Mr. Burrows pointed out the many problems associated with fabricating an absolutely leakproof vehicle to contain a man in space in a "shirt sleeve" atmosphere. To illustrate the dangers of a leak in such a container, he showed a film of the forces acting on a body in the vicinity of such a leak. As far as materials of the future space craft, he pointed to columbium alloys and other refractory metals as the only ones capable of withstanding the friction heating caused by the reentry of the vehicle into the earth's atmosphere. He emphasized that weld quality must be even higher in the future because the structure's integrity must be at its optimum for it to carry out its mission.

Perry Rieppel, chief of the joining division at Battelle, who was a recent IIW delegate at Yugoslavia in 1959 described his impressions of the attitude of the major foreign areas toward welding.

Mr. Rieppel felt that, in all major parts of the world, foreign welding operators and technology will be strong competitors. All countries are training more welders and welding engineers, some countries are interested in fundamental research, and some in engineering development; so that, in the over-all picture, the U. S. must dig in to keep ahead of the rest of the world in welding.

Last to speak, but not least important, was Mr. Plummer. Mr. Plummer described three AWS activities for the near future that are of interest to the New York Section. First, he described the new series of courses in welding for engineers that will be held in New York early this year. This is an opportunity for companies to send competent personnel to obtain an excellent welding training.

Secondly, he described the new United Engineering Center to be built here. This new home of the AWS will be a showplace of the city.

In conclusion, Mr. Plummer announced that the Annual Assembly meeting of the International Institute of Welding is to be held in New York in April 1961. The AWS will be a sponsor of this meeting and the New York Section will be called on to help in making this important meeting a huge success.

HEAVY WELDMENTS

Olean—On November 17th, 39 members and guests of the *Olean-Bradford* Section gathered at The Castle in Olean for dinner and the third section meeting of the season. Due to a last minute change in plans, the original speaker, Frank Iapalucci could not attend. His place was taken by A. J. Raymo, factory manager at the Eddystone Division of Baldwin-Lima-Hamilton Corp.

Mr. Raymo gave a very good slide-illustrated talk on various heavy fabrication jobs completed by his company. He discussed some of the problems that any specialty shop should consider about a job before accepting it.

Of special interest were several slides showing fabrication of steam locomotives that the Baldwin division has worked on in past years.

WELDING OF ALLOYS

Rochester—The *Rochester* Section held its November meeting at the Liederkranz Club on November 16th, with dinner followed by an interesting and educational talk given by L. Haslip and B. Payne of the Pfaudler Co., division of Pfaudler Permutit, Inc., Rochester, N. Y. Their talk was on the "Welding of Titanium, Zirconium and Tantalum."

The talk was accompanied by slides that showed the use and importance of keeping these metals in an inert atmosphere or a vacuum at elevated temperatures.

After the talk, both Mr. Payne and Mr. Haslip were kept busy for some time answering questions.

Ohio

HARD SURFACING

Cleveland—A panel discussion on "Industrial Applications of Hard Surfacing" attracted a large turnout at the December meeting of the *Cleveland* Section. Numerous questions during the open part of the meeting indicated the intense area interest in the subject matter.

The panel, chairmanned by R. P. Tarbell, consisted of I. W. Evans,

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HARD SURFACING IS SUBJECT

December 9th meeting of Cleveland Section featured a panel discussion on applications of hard surfacing. Left to right are: Harry Zeskey, John Wischusen Panel Chairman R. P. Tarbell, S. T. Heald, and I. W. Evans

Morgan Engineering Co.; S. T. Heald, Republic Steel Corp.; John Wischusen, Cleveland Hard Facing Co.; and Harry Zeskey, Republic Hard Facing Co. All these men are considered experts in their own area of hardsurfacing.

Subject matter ranged from intricate applications in the trucking industry and metal-overlay field to the massive blast furnace bell and hopper hard surfacing in steel mills. The discussion pointed up the practical and economical aspects of hard-surfacing applications.

SAFETY IN WELDING

Columbus—The *Columbus* Section held its regular scheduled meeting on November 13th at the Dragon Restaurant. Forty members attended the dinner and meeting. The speaker for the evening was A. N. Kugler, chief welding engineer, Air Reduction Sales Co., New York. His talk was on "Safety in Welding and Cutting." Mr. Kugler presented two slide films on the subject of safety. The first slide film, "The Guy Behind Your Back," covered oxyacetylene welding and cutting safety. The second film "Always on the Job" covered arc-welding safety practices. In addition to showing the films, Mr. Kugler discussed various aspects of safety problems.

FLUX-CORED CO_2 WELDING

Columbus—The *Columbus* Section met on December 4th for dinner and a technical meeting at the New Berwick Seafood Manor. The largest December turnout of members in recent years was augmented by several new faces attending as guests of their employers. The speaker, James A. Howery of the National Cylinder Gas Co., presented a "Progress Report on the Flux-Cored CO_2 Welding Process."

Mr. Howery traced the development of flux-cored CO_2 welding to its present state. Several examples of commercial application were illustrated by slides and also by motion pictures. Weld properties obtainable with the process were discussed as applied to mild and low-alloy steels. Cost comparisons were made for a variety of applications in diverse industries. A question-and-answer period followed the formal talk which permitted those attending to draw on Mr. Howery's experience.

RESISTANCE WELDING

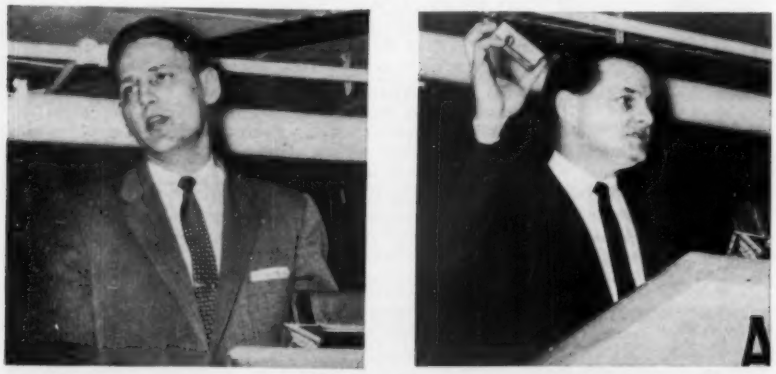
Dayton—Fifty members and guests enjoyed a roast turkey dinner prior to the *Dayton* Section's December meeting held at Kuntz's Cafe on Tuesday evening, December 8th. Guests included William Craske, chairman of the Chicago Section; Bob Heller, Gary, Ind.; Fred Berry, Denver, Col.; Dallis Kirk, Scotts Bluff, Neb.; and Francis Owen, Kankekee, Ill. These men were attending the Hobart Bros. Trade School.

The speakers for the evening were L. W. Mecklenborg and A. W. Schueler of the Research and Development Department, Precision Welder and Flexopress Corp., Cincinnati, Ohio.

Mr. Mecklenborg showed slides of typical and unusual industrial applications of the foil butt-seam welding process. He explained how the process required less power demand and produced less warpage due to the foil method of welding a seam.

Mr. Schuler explained the development and illustrated the usage of the magnetic-force welding machine in welding brackets to painted and vinyl-coated steels. The samples shown were Hi-Fi cabinets and small radio cases.

SPEAK ON RESISTANCE-WELDING APPLICATIONS



L. W. Mecklenborg (left) and A. W. Schueler spoke on specialized resistance-welding applications at the December 8th meeting of Dayton Section

WELDING OF ALLOYS

Youngstown—"How to Catch a Cold" was the coffee-hour film, but 45 members and guests caught a very fine talk on "Recent Developments in Welding High-strength Steels and Titanium" at the November 19th dinner meeting of the *Mahoning Valley* Section held in the Victoria Restaurant in Youngstown. Program Chairman Jack Huna introduced the speaker, Carl E. Hartbower, chief, Metals

COVERS WELDING OF STEELS AND TITANIUM

The special techniques required for welding high-strength steels and titanium alloys were described by Carl E. Hartbower at the November 19th meeting of Mahoning Valley Section. Left to right are: J. Huna, Mr. Hartbower, Section Chairman E. A. Craig and R. Hoffman

Joining Branch, Watertown Arsenal Laboratories.

Mr. Hartbower's informative 90 min talk was supplemented by slides and covered the various problems encountered in welding the various types of titanium available today. He mentioned that the first approach used by Watertown Arsenal in the welding of titanium was a method that could be used in open air. This idea was developed to preclude the difficulties and limitations of welding in a chamber. He also covered the problems they encountered with respect to increase in hardness and strength but loss in ductility and notch toughness when welding.

Protection of the weld from contamination from air was the major problem to lick when welding. Results showed that about 1% of oxygen or hydrogen caused serious embrittlement; therefore, the maximum gas that could be tolerated is approximately 0.15% oxygen and hydrogen and 0.05% nitrogen. To protect the weld, a trailing shield was used that followed the torch using a gas coverage and copper backup on the underside.

The comparison of steel and titanium with respect to strength-weight ratio was then discussed. It was pointed out that titanium at 115,000 psi was equal to steel at 200,000 psi.

Slides showing the ductility and strength of various types of titanium were then shown. Comparison of welding $^1/_8$-in. thick type Ti-6AL-4V using gas-shielded metal-arc welding process at 75 ipm arc-travel speed and 129 to 134 ksi strength and $^1/_4$-in. type Ti-5AL-4V at 27 ipm and 132 to 135 ksi were made. These were the strength properties of the weld metal and not the heat-affected zone.

The use of low-carbon martensite, such as types 2512, 4312 and 4812, was then covered by Mr. Hartbower. These materials have a great strength-weight ratio and a high ultimate strength. Since prime, untempered martensite is strong and ductile, the idea when welding was to get as much martensite as possible around the welded joint during weld. The Watertown Arsenal used cold CO_2 as a gas quench from a shield following the welding torch which obtained more martensite.

The use of preheat and postheat in welding of high-strength steels of 200,000 psi yield was also briefly discussed. A short-time postheat by the use of an induction coil to get useful ductility was also described.

Following the main speech, a question-and-answer period brought forth the many future uses being contemplated for the titanium industry and the space-age potential of this material.

SURFACING FACTS

Bucyrus—The December meeting of the *North Central Ohio* Section was held at the American Legion Home in Bucyrus on the 3rd of December. Fifty members were in attendance.

Chairman Rawlinson read a telegram from H. E. Schultz, Director of District No. 5, commending the section on being the first in the

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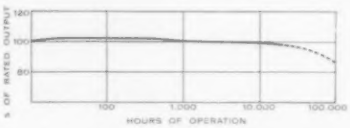

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OXYGEN CUTTING

R. L. Deily (left) guest speaker at the December 7th meeting of Lehigh Valley Section is shown with Chairman L. R. Constantine. Oxygen cutting was the topic

WELDING OF ALUMINUM

The welding of aluminum was explained by I. A. MacArthur at the November 16th meeting of Philadelphia Section. He is shown above (center) discussing the subject with Sam Reynolds (left) and Bob MacCrackin

District to fulfill their quota for the United Engineering Fund.

Walter Edwards, program chairman, presented a most enjoyable movie on "Fishing in Alaska" sponsored by the American Motors Corp. and the local Rambler dealers.

William Lutes, manager, Hard Surfacing Dept., the McKay Co., York, Pa., was the featured speaker for the evening and presented a very interesting and educational talk, accompanied by slides, on various hard-surfacing problems, including the reasons for hard surfacing and methods of selection of rod and applications.

William Flavel and Edward Smith, sales representatives of the McKay Co. were guests at this meeting.

FABRICATION PROCESSES

Canton—The November meeting of the *Stark Central* Section held on November 11th was preceded by a social get-together and dinner at the American Legion in Canton.

Featured speaker was Bert Haver, welding specialist of the Union Metal Manufacturing Co., Canton.

Mr. Haver was the first local speaker in the history of the Section. His subject was "Processes Used at Union Metal" and was not only well presented, but furnished an insight into some of the facts concerning local industries. The problems mentioned in his talk were understandable to all, and the general reaction was "why don't we do this more often."

Methods used in welding, arc timers, galvanizing, forming and other processes were generally mentioned, and were of interest to all.

Present with Mr. Haver were W. F. McDermitt and N. R. Foltz, who aided with the movies and in the presentation of added facts.

AWS TECHNICAL ACTIVITIES DESCRIBED BY PANEL

The December 4th panel discussion of the Philadelphia Section was devoted to a complete coverage of the technical activities of the AWS. Standing (left to right) are Moderator J. J. MacKinney and Panel Discussion Chairman F. Hussey. Seated, in same order, are panel members E. A. Fenton, Art Kugler and B. E. Rossi

Pennsylvania

OXYGEN CUTTING

Allentown—Forty-three members and guests of the *Lehigh Valley* Section met on December 7th at Walp's Restaurant for dinner and meeting. The speaker was Richard L. Deily of the Messer Cutting Machines, Inc., New York, N. Y. The subject of his talk was "What's New in Cutting." The coffee feature was the showing of a film entitled "The DEW Line Story" a color film on the construction of the Distance Early Warning Line in the Antarctic.

PRESSURE-VESSEL FABRICATION

Titusville—Eighty members and guests of the *Northwestern Pennsylvania* Section braved extreme cold and dangerous driving conditions to attend a meeting held in Titusville at the Drake Hotel on November 17th. Many cancellations were sent in because of the bad weather conditions.

Those who attended were rewarded with a very fine talk on "Materials and Design for Pressure-Vessel Fabrication" as given by R. W. Bennett, chief metallurgical engineer of the General Engineering Service Division of Alco Products, Schenectady, N. Y.

Mr. Bennett told his audience that successful presure vessel or any other fabricated structure can be economically built to the quality level required if there is close cooperation between the designer, metallurgist, welding engineer and the shop.

He emphasized the importance of choosing the proper materials for fabrication and service, determining the welding process, electrodes and procedure to obtain the strength and soundness of the weld metal required, designing the weld joint properly, proper control of the welding process and operation during fabrication, and last, but not least, good judgment.

Mr. Bennett supplemented his detailed talk by showing slides to illustrate various points. His talk touched on every facet of pressure vessels, including such things as the Boiler Code and its significance.

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ALUMINUM WELDING

Philadelphia—The *Philadelphia* Section had an unusually large turnout of 106 members and guests at its November 16th meeting to hear I. A. MacArthur speak on the subject of "Aluminum Welding, Past, Present and Future."

Mr. MacArthur traced the production of aluminum from the very mining of "bauxite" to the use of welding in the fabrication of aluminum. The presentation was very informal. The speaker requested the audience to break in at any time during his talk with any questions or discussion. This idea seemed to be popular as the discussion lasted for two hours and provoked a great deal of interesting conversation.

Chairman Frank Iapalucci had made a special appeal to the membership to make a special effort to attend this meeting, in view of the fact that the speaker was recognized as an authority on welding and the near-capacity attendance was gratifying to both Mr. Iapalucci and Mr. MacArthur.

Mr. MacArthur is head of the Welding Branch, Metallurgical Laboratories, Olin Mathieson Chemical Corp., fourth largest producer of aluminum in the USA.

GIVE TALK ON ALUMINUM STRUCTURES

On November 19th, the members of the Pittsburgh Section heard a talk on the designing and welding of aluminum structures by R. K. Sager, H. N. Hill and R. Kasser. Posing for the cameraman are (left to right) D. H. Marlin, Mr. Sager, W. M. Rogerson, Mr. Kasser and Mr. Hill

AWS ACTIVITIES

Philadelphia—Those attending the *Philadelphia* Section's December 4th panel meeting left with a much better understanding of AWS activities. Few members realize how much effort goes into the activities of their SOCIETY or how much service they can receive from the SOCIETY to aid them in their daily welding problems.

J. J. MacKinney, chairman of the Technical Activities Committee, served as moderator for the panel.

B. E. Rossi, editor of the WELDING JOURNAL and secretary of the AWS Technical Papers Committee, described the task of publishing the JOURNAL and the processing of technical papers.

A. N. Kugler, chief welding engineer, Air Reduction Sales Co., and former chairman of the AWS Technical Activities Committee, explained the functions of this committee.

E. A. Fenton, AWS technical secretary, explained the many problems involved in the drafting and distribution of publications.

During discussion it was brought out that the SOCIETY sponsors an extremely large number of committees, formulates many codes and standards, and issues many publications intended to solve welding, brazing and soldering problems. Also, as one of the American sponsors of the International Institute of Welding, it cooperates with other countries throughout the world. These activities make membership in AWS one of far-reaching consequence.

At the close of the evening, it was urged that all other Sections should have an opportunity to hear what this group has to say.

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HOUSTON SECTION HOLDS SOCIAL AFFAIR

The 1959 Spring Social of the Houston Section was a truly gala and festive event. Above are the officers for the 1950–60 fiscal year and their smiling wives. Chairman and Mrs. M. Avis are the fourth couple from left, front row

Pictured above with their charming ladies and with Past-chairman H. Crick are some of the instructors who started the Section's first welding school in the Fall of 1958. The gentlemen in question are (left to right) R. E. Pechacek, L. F. Megow, Mr. Crick, A. E. Wisler, L. D. Deere and W. Greer

CLADDING AND MAINTENANCE

Pittsburgh—On Thursday evening, November 12th, the scheduled *Johnstown Sub-Section* meeting was attended by a good crowd. There were 34 members and guests present for dinner. Two more members and their three guests, students from the University of Pittsburgh, Johnstown Center, joined the others for the meeting.

After a film presentation entitled "Resistance Welding," furnished by Webber Brothers, Chairman P. Hershberger presented an interesting and informative illustrated lecture on "Metal Cladding and Maintenance Welding." His presentation was well received and numerous question were asked.

The Section was pleased to have both H. Ed Cable and J. F. Minnottee in attendance. Their presence added a lift toward the attainment of the Section-level goal.

WELDED STRUCTURES

Pittsburgh—One hundred and five members and guests were present at the November 19th dinner meeting of the *Pittsburgh* Section held at Mellon Institute. The dinner portion of the meeting held in the Hunt Room of the Hotel Webster Hall was also well attended.

Plans were discussed for an educational course on welding construction and design to be given every Tuesday evening from February 9th through March 15th.

W. M. Rogerson, a member of the Executive and Program Committee, introduced the speakers. Due to the fact that P. B. Dickerson was ill, Dick Sager substituted for him and gave a talk on the mechanical properties of arc welds in various alloys. H. N. Hill followed with a discussion on new concepts for design, and Richard Kasser completed the presentation with a talk on aluminum structural applications. All of the speakers are associated with the Aluminum Company of America in New Kensington.

Lantern slides were used by each speaker to illustrate his talk. A period of general discussion followed the presentations.

Rhode Island

WELDING IN RUSSIA

Providence—The *Providence* Section held its monthly dinner meeting at Johnson's Hummocks on Wednesday, November 18th. Thirty-seven members and eight visitors were present to hear Clarence E. Jackson, staff engineer of the Linde Development Laboratory, give a lecture.

Mr. Jackson told some of the highlights of his recent trip to Russia. He mentioned the welding processes being used by the Russians and some of the conversations he has had with the Russian people.

His technical talk, entitled "Basic Fundamentals of Welding," was accompanied by a very interesting variety of colored slides.

GAS METAL-ARC WELDING

Providence—The *Providence* Section held their monthly dinner meeting at Johnson's Hummocks on Wednesday, December 16th.

Roger W. Tuthill, assistant manager of the Development Department, Air Reduction Sales Co., Union, N. J., gave an interesting talk entitled, "Practical Aspects of Consumable-electrode Welding." Accompanying the talk were slides and a sound, color movie, taken at a speed of 3500 frames per second which illustrated a consumable-electrode welding arc in action, welding aluminum, stainless steel and magnesium.

A turnout of 38 members and seven visitors was present. A special buffet dinner was served, which was enjoyed by all.

Tennessee

WELDING OF ALUMINUM

Kingsport—The *Holston Valley* Section met for dinner and meeting at the Kingsport Inn on November 17th. A social hour was held before the dinner.

Program Chairman Conley Scott introduced the speaker for the evening, Howard Adkins of the Kaiser

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The new Monautronic V-2 welding control introduces the concept of feedback control to produce spotwelds of consistently high quality. It makes use of the latest advances in electronic computing to overcome automatically such obstacles to weld quality as line voltage fluctuation, electrode wear, variations in electrode tip force, surface finish and shunting.

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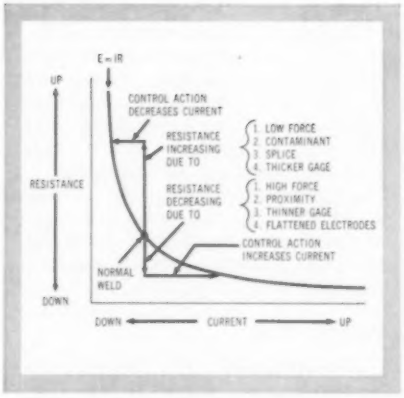

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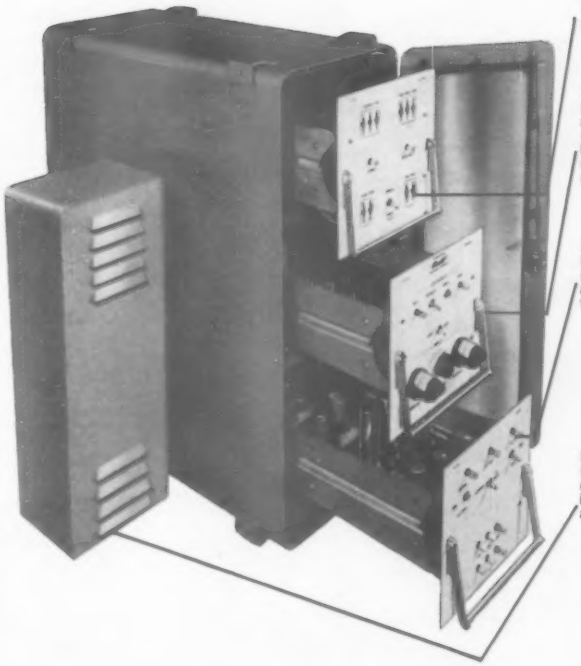

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DISCUSSION ON WELDING OF ALUMINUM IS PRESENTED

Howard E. Adkins discussed the welding of aluminum by the gas-shielded processes at the November 18th meeting of the Houston Section. This is part of the large crowd on hand. Shown at speaker's rostrum are (left to right) D. J. Middlehurst, Mr. Adkins and Section Chairman M. C. Avis

Aluminum and Chemical Sales, Inc., Chicago, Ill. Mr. Adkins gave a very constructive and informative talk on types of aluminum, their weldability, and the various uses now developing for these alloys. He used slides to illustrate his talk and then showed a movie on the welding of aluminum.

There were 21 present for the dinner and 31 for the meeting.

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Texas

ALUMINUM WELDING

Houston—Ninety members and guests attended the November 18th meeting of the *Houston* Section held at the Houston Engineering and Scientific Society. An interesting color movie on "Hunting" was shown prior to the meeting.

Technical speaker was Howard Adkins, welding specialist in the District Engineering Department of Kaiser Aluminum and Chemical Sales. He presented a 75-minute talk, accompanied by slides and movies on the "Welding of Aluminum."

WELDING OF ALUMINUM

Dallas—On December 8th, 32 members and guests of the *North Texas* Section gathered at Western Hills Inn for dinner and a most interesting presentation by Donald Krezek, sales manager, Hevi-Duty Electric Co., Regulator Division, Milwaukee. The subject of Mr. Krezek's presentation was "Tungsten-Arc Welding of Aluminum." The main attraction was a high speed film (2400 frames per second) of the "square-wave arc" produced by the "square wave" welding machine.

PLANT VISIT

San Antonio—The *San Antonio* Section enjoyed a visit to the City

EXPLAINS TUNGSTEN-ARC WELDING OF ALUMINUM

The subject of Donald Krezek's address at the December 8th meeting of North Texas Section was the inert-gas-shielded tungsten-arc welding of aluminum. Left to right are A. W. Anderson, R. G. Dance, L. Hudson, Mr. Krezek, J. Davis and E. Boruch

SPEAKS ON AUTOMATIC WELDING

The November 20th meeting of Fox Valley Section featured a talk by John H. Headapohl on the subject of automatic welding. Left to right are pictured J. Teigen, Mr. Headapohl, R. Hart and Section Chairman Max Kern

Public Service Board's Mission Road Power Plant in San Antonio. This plant, the smallest of the three owned by the city, has a capacity of generating 150,000 kw, consisting of two 25,000-kw units and one 100,000-kw unit.

The 100,000-kw unit is housed in a ten story all-welded steel structure, suspended from the top. The generator for this unit is in the process of being completely overhauled. Dismantling began with removing the insulation from around the pipe and heat exchanger which was five or six inches in thickness at spots.

Examples of excellent high-pressure welds on the piping were evident, some of which were in difficult positions for welding.

A. J. Bell, maintenance supervisor for the City Public Service Board, supervised the activity.

Utah

MEETINGS TO DATE

Salt Lake City—The first meeting of the season was held by the *Salt Lake City* Section on Sept. 17, 1959. It consisted of a tour of the American Foundry plant in which 40 members participated. Dinner and discussion followed at the Desert Inn.

Forty-eight members and guests enjoyed a special program furnished by Past-chairman Ray Potts at the October 15th meeting held at the Desert Inn. A film "Touring the West" was one of the features of the program.

R. W. Tuthill, assistant manager of development for Air Reduction Sales Co., was the speaker at the November 12th meeting held at the Panarama Inn. The subject of his talk was "Fundamentals and Applications of Consumable-Electrode Welding."

The Annual Christmas Party was held at the Elks Club on December 4th. Some 116 members and guests had a very enjoyable time.

Wisconsin

AUTOMATIC WELDING

Appleton—The *Fox Valley* Section met on November 20th at the Appleton Elks Club.

John H. Headapohl, manager, Automatic Welding Division, Hobart Brothers Co., gave a non-technical talk, covering submerged-arc and gas-shielded metal-arc welding. The use of a constant-voltage welding machine as a simplified tool for high-production welding was explained. Slides showed actual automatic welding installations.

The meeting was well attended and Mr. Headapohl's talk was well received.

WELDING PROCESSES

Madison—The *Madison* Section held its regular monthly meeting on November 19th at the Eagles Club in Madison.

The speaker was Ted Jefferson, editor of the *Welding Engineer*. His subject for the evening was "What Is New in Welding Processes?"

Eighty men and two ladies attended the dinner and technical talk. This meeting was held in conjunction with the Welding Institute at the University of Wisconsin on Stainless-steel Fabrication.

Several of the past and present officers participated on panels during this institute.

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New Members

EFFECTIVE DECEMBER 1, 1959

MEMBERSHIP CLASSIFICATION

A—Sustaining Member
B—Member
C—Associate Member
D—Student Member
E—Honorary Member
F—Life Members

TOTAL NATIONAL MEMBERSHIP

Sustaining Members	199
Members	6,240
Associate Members	5,725
Students	276
Honorary Members	9
Life Members	16
Total	12,465

AWS Builds Men of Welding

ANTHONY WAYNE

Houser, Burdette (B)

ARIZONA

McLaughlin, Roy E. (B)

BATON ROUGE

Boxill, Herbert J. (B)
Brou, Harold J. (B)
Galloway, A. D. (B)

BIRMINGHAM

Baldwin, Truman J. (C)

BOSTON

Brigham, Paul W. (C)

BRIDGEPORT

Chillemi, John (C)
Elliott, Harry (C)
Jones, Charles J. (C)
Seravalli, John J. (B)

CANADA

Carmichael, Stewart John (B)
Hirschfield, John A. (B)

CAROLINA

Alexander, William T. (B)
Baird, William H. (B)
Hay, James T. (B)
Williams, Kenneth E. (B)

CHATTANOOGA

Clark, James W. (B)
Hickey, John O. (C)

CHICAGO

Burdick, Neal M. (C)
Butler, Lester A. (C)
Cash, Marshall (B)
Di Verde, John H. (B)
Galambos, Richard G. (C)
Goddard, Edward D. (B)
Jennings, Travis L. (C)
Kolofa, Donald W. (C)
Lachnowicz, Leo S. (C)
Lee, Ken (C)
Mann, Robert F. (C)
McMillan, Charles H. (C)
Pickhaver, Lionel G. (B)
Sandusky, Harold E. (B)
Stafford, Edward (C)
Vesper, Phil (B)

CLEVELAND

Holliday, Homer E. (B)
Learned, Addison W., III (D)
Polster, Lewis H. (B)
Schneider, Richard T. (C)

COLUMBUS

Cordea, James N. (C)
Elkins, Billy Robert (B)
Kolozs, Gaspar (D)
Lutz, Louis (B)
Nelson, Jerome Wm. (B)
Ruff, Edward C. (D)

DAYTON

Whitlow, G. R. (C)

DETROIT

Black, George, Jr. (B)
Hicks, James H. (B)
Mertz, Ralph H. (B)
Visconti, Chas. J. (B)
Winkler, Raymond E. (B)

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Corboy, Robert J. (C)
Esty, Howard (C)
Farrar, Russell (C)
Freedman, Bernard Joseph (B)
Gallivan, James E. (B)
Leahy, James J. (C)
Olson, Ivar B. (C)
Riggott, Claude L. (B)
Simko, Joseph A. (C)
Sorrell, Frank E. (C)
Thomas, Bernard (C)
Zeil, Harry C. (B)

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Cobb, F. Howard (B)
Dobkins, Kenneth B. (C)
Dorrell, Will R. (B)
Floyed, H. J. (B)
Heldermon, J. Earl (C)
High, J. D. (C)
Williams, Clifton K. (B)

IOWA

Koos, William J. (C)

J. A. K.

Babcock, J. H. (B)

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Anselm, J. J. (C)

LONG ISLAND

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Weisser, Eugene F. (C)

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Churchill, Edward A. (B)
Evans, William L. (D)
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Kunert, Wesley (C)
Lishman, Clarence (C)
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Yoneda, Min (D)

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Leinfelder, John F. (B)

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(Continued on page 176)

30-ton gyratory...

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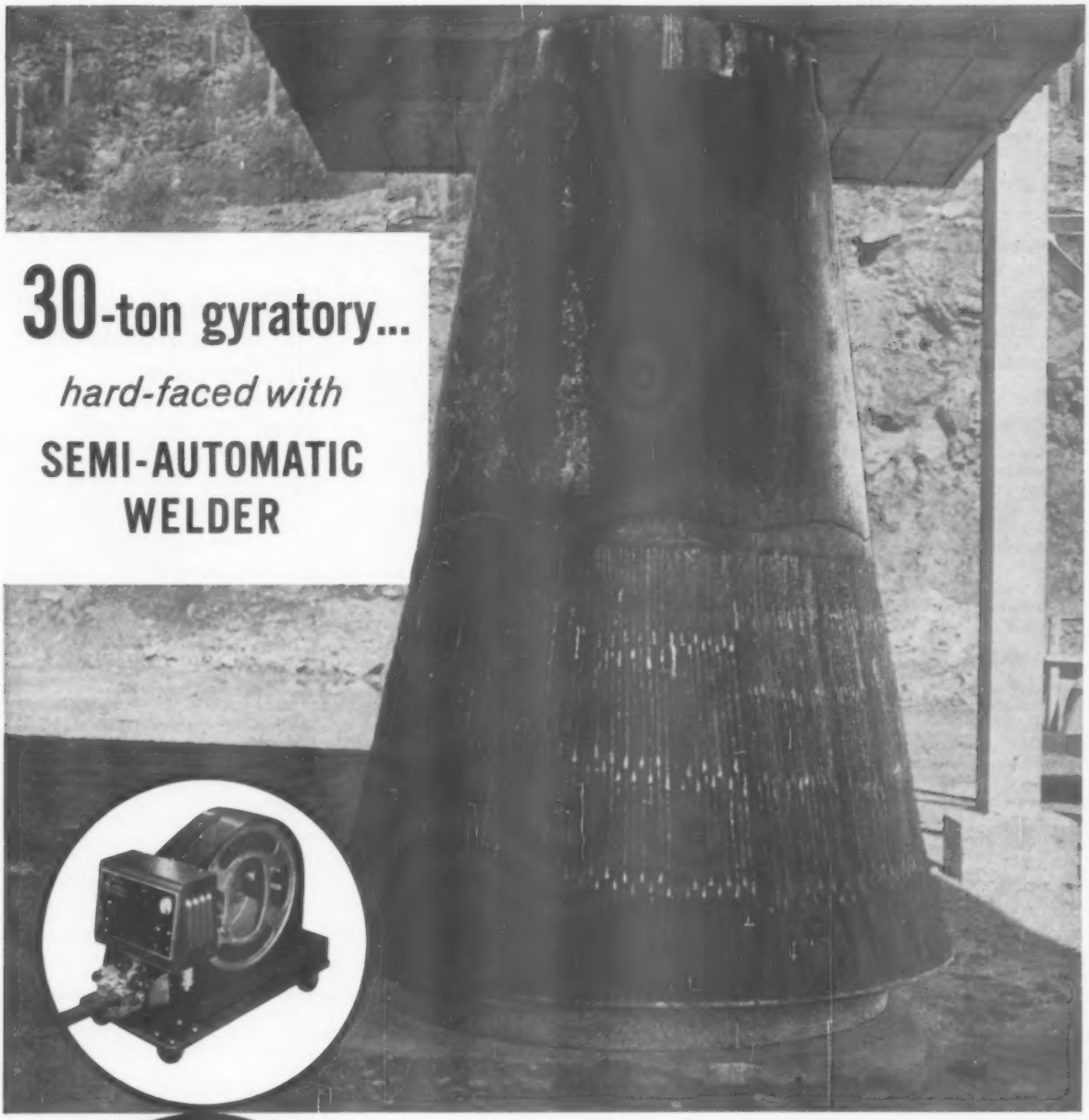

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Montalbo, George (D)

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WESTERN MICHIGAN

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Hillock, Jeff (D)
Lankenau, Arnold C. (C)
Mead, Dennis C. (D)
Smith, Sherman (D)
Velden, Roger Vander (C)

WICHITA

Rousseau, Kenneth Earl (C)

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Virgets, N. M. (C to B)

BIRMINGHAM

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CHICAGO

Boersma, Ed (C to A)

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Why: To give him a grasp of the fundamentals of a specialized group of processes and introduce him to applications, relative costs, and design considerations.

Enrollments are limited to fifty and lists will be closed immediately after fifty applications have been accepted. Plan to attend this course and take advantage of the latest and most authoritative information on Gas-shielded Welding Processes. Send for prospectus and application form immediately, by addressing Arthur L. Phillips, Secretary, Information & Education, 33 W. 39th St., New York, N. Y.

NO. 2 OF A SERIES
"How to Design Welded Aluminum Structures"

New Alcoa Yield Strength Concept Reveals Latent Strength of Welded Aluminum

Mr. Harry N. Hill, *Engineering Design Division Chief, Alcoa Research Laboratories, Aluminum Company of America reports research findings presented at the 1959 annual meeting of the American Society of Civil Engineers.*

This is the second in a series of informational articles describing new concepts in the strength and characteristics of welded aluminum. Reports in this series are based on extensive, continuing investigation at Alcoa Research Laboratories, where advanced methods for the use of aluminum structures are being explored.

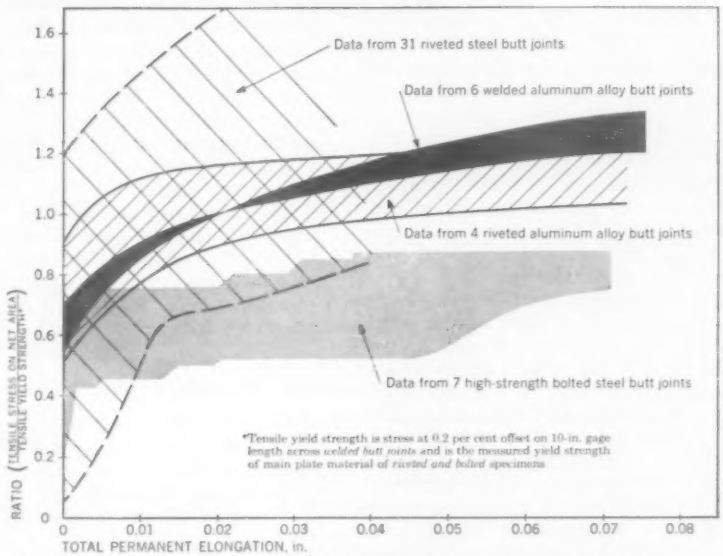
Use of the 10-in. gage length concept recommended here generally produces yield strength values from *30 to 40* per cent *higher* than minimum yield strengths found in and adjacent to welded areas! Adoption of this new design rule will enable designers to take full advantage of the strength of aluminum in welded structures.

In actual practice, it has often been found that the suitability of a structure is not determined by its ultimate strength but by its ability to carry load without significant yielding or permanent deformation. Design of these structures is based on yield strength of the material, modified by an appropriate factor of safety.

Yield strength of aluminum alloys is the axial stress that will produce a permanent change in length of 0.2 per cent in the portion of a standard test specimen having a uniform cross section. In this test, the length for measurement is unimportant, although a 2-in. gage length is commonly used.

If the test specimen contains a butt-welded joint at the middle of the length of uniform cross section, yielding will occur first in the immediate vicinity of the weld, because the heat of welding has softened the metal in this region. The yield strength value of such a piece will, therefore, depend upon the gage length tested.

Experience tells us that it is not reasonable to base a design on the yield strength of the material in and adjacent to the weld since yielding confined to these regions is so localized that the total effect on a welded structure is insignificant. To provide more realistic yield strength values across a welded joint, *it is advocated that such values be determined as the stress corresponding to 0.2 per cent permanent set on a 10-in. gage length.* This permits inclusion of some high-strength material unaffected by the heat of welding. Verification of this technique has been achieved in extensive tests at the Alcoa Research Labs. A future article in this series will provide further supporting data.


Data from 31 riveted steel butt joints
Data from 6 welded aluminum alloy butt joints
Data from 4 riveted aluminum alloy butt joints
Data from 7 high-strength bolted steel butt joints
*Tensile yield strength is stress at 0.2 per cent offset on 10-in. gage length across welded butt joints and is the measured yield strength of main plate material of riveted and bolted specimens
RATIO (TENSILE STRESS ON NET AREA / TENSILE YIELD STRENGTH*)
TOTAL PERMANENT ELONGATION, in.
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08

Permanent Elongation of Welded, Riveted and Bolted Joints

A basic premise of this new concept was that a welded aluminum joint should function much as a riveted or bolted joint. The chart demonstrates that the nature of the yielding of *welded aluminum* alloy butt joints based on the 10-in. gage length yield strength is *about the same* as that in *riveted or bolted joints* of aluminum alloy or steel.

The first article in this series of new design concepts for welded aluminum structures dealt with the "reduced-strength zone." Subsequent subjects will feature strength of welded members in tension, strength of welded members in compression, strength of welded beams, fillet welds and design data.

For top quality aluminum welding products such as consumable electrodes, welding and brazing rods and fluxes; and solder and soldering fluxes; contact your nearest Alcoa sales office. For more complete information on "Designing Welded Aluminum Structures," write Aluminum Company of America, 1762-B Alcoa Building, Pittsburgh 19, Pa.

Your Guide to the Best in Aluminum Value

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For details, circle No. 30 on Reader Information Card

NEWS of the industry

6½ Million-dollar Bonus Paid by Lincoln

The Lincoln Electric Co. paid its 1371 employees in Cleveland and its 38 district offices throughout the country $6,488,167 in annual incentive pay. Each employee received a check representing payment for his or her extra contribution to the success of the company for the year. The amount of each check was determined by an individual merit rating of performance on the job for the year.

Lincoln has paid this incentive every year since 1934, during which time the company has paid a total of $93,985,308 in addition to regular earnings and other benefits all of which are standard for the industry. This year the company also purchased $1,000,000 in retirement annuities covering each employee. The company also guarantees continuous employment to all employees with over two years' service, thus securing them against lay-offs.

A. O. Smith Expands

The A. O. Smith Corp. announces that it is increasing the manufacturing floor space at its Welding Products Division plant in Elkhorn, Wis., by more than 25%. The recent plant addition consists of an assembly area that adjoins the former plant structure.

Also announced is Smith's purchase of about 7½ acres of farm land adjoining its Elkhorn plant as insurance for the continued growth of its welding business. Ultimate use of the land, bought from the Elkhorn Development Corp., has not yet been determined.

Precision Welder Makes Appointments

The new manufacturing plant recently completed for Precision Welder and Flexopress (Canada) Ltd. at 72 Carnforth Rd., Toronto 16, Ont., will also house the headquarters personnel, it was announced recently.

Staff changes include the appointment of William Amos as manager of engineering and sales and Albert Moore as manager of manufacturing. Both men have been closely associated with the manufacturing and marketing of this company's products in Canada for several years.

The company is affiliated with Precision Welder and Flexopress Corp., of Cincinnati, and will now manufacture as well as market the complete line developed by the American company.

McKay Enlarges Plant

The McKay Co. has broken ground in York, Pa., for a $500,000 expansion program which will provide greater capacity for manufacturing of electrodes and welding wire.

The plan as outlined will also include provision for a greatly enlarged laboratory for research in the field of electric arc-welding technology. The laboratory staff has been expanded.

Lenco Buys Pike Products

Lenco, Inc., makers of the Hi-Amp accessory line, have announced the purchase of Pike Products, Inc., formerly known as H. J. Wagner Products Co. According to Paul J. Leonard, president, Lenco will resume manufacture of Pike products under the Pike name in addition to its usual line.

General Mills Acquires Magnaflux

General Mills, Inc., has announced that it has acquired the business and assets of Magnaflux Corp. of Chicago, Ill., pioneer in the development of techniques and equipment for detecting hidden flaws in industrial materials.

Magnaflux Corp., a leader in non-destructive testing, will continue in business at its present location in Chicago and under the same name as a wholly owned subsidiary of General Mills, independent of other divisions.

Record Sales for Air Reduction

Sales of Air Reduction Co., Inc., for nine-months ending Sept. 30, 1959, were a record $151,052,893, compared with sales of $128,771,375 for the first nine months of 1958, an increase of 17.3%, it was announced recently. Net income for the first nine months of 1959 was $11,444,702, compared with $9,756,071 for the first nine months of 1958, also an increase of 17.3%.

Sales for the third-quarter of 1959 were $49,216,034, compared with sales of $43,153,307 during the third-quarter of 1958, an increase of 14%. Third-quarter 1959 net income was $3,627,580, compared with third-quarter 1958 net income of $3,199,688, an increase of 13.4%.

COMING EVENTS

A Calendar of Welding Activity

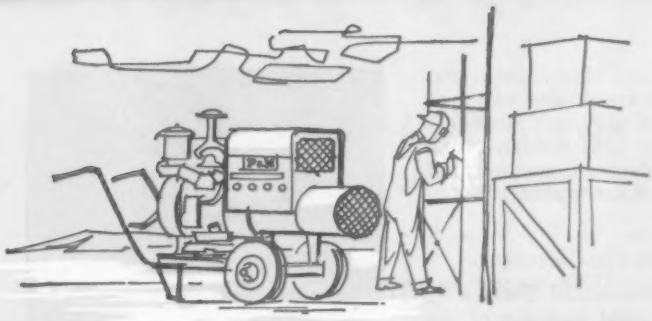
AWS National Meetings

41st Annual Meeting:
April 25–29, 1960. Biltmore Hotel, Los Angeles, Calif.
Exposition: April 26–28
Great Western Exhibit Center

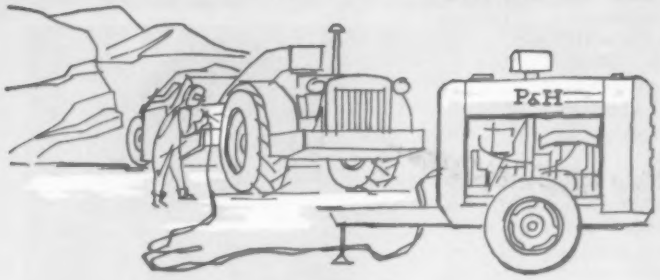
1960 National Fall Meeting. September 26–29. Penn Sheraton Hotel, Pittsburgh, Pa.

NWSA

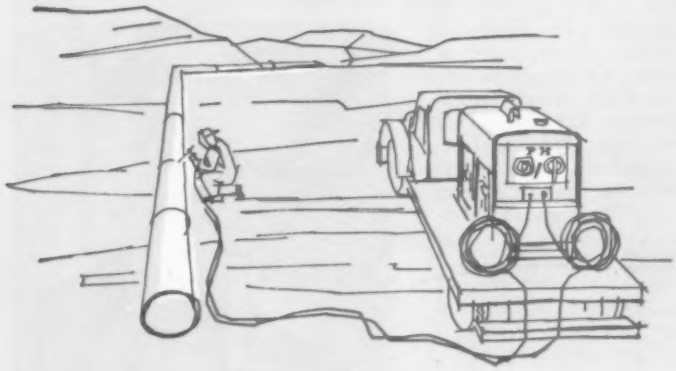
May 5–7, 1960. 16th Annual National Convention, Palmer House, Chicago, Ill.



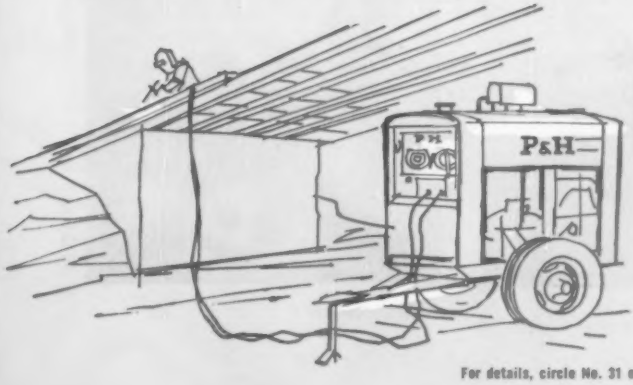
eliminate rewelds



and callbacks



with P&H portable welders



6 engine-driven models for field welding in the 25- to 500-amp. range

Put your out-of-shop welding on a paying basis by welding the job right the first time. You can do it with portable, self-contained P&H engine-driven welders.

Here's why: Accurate voltage control enables operators to make precise settings and re-settings without "jockeying" or other adjustments. Superior current stability — even at extreme ends of range — permits deep penetration without burn-through. Instantaneous recovery maintains 100% arc stability throughout the welding cycle, thus preventing popouts.

The built-in controls simplify welder operation. They enable operators to weld faster — and to lay down stronger, cleaner welds the first time. As a result, there's no need for rewelds or costly call-backs.

P&H welders are built to give long-life, low-cost welder service — to withstand hard use and rough handling in the field. They need less care because all non-essential parts have been eliminated. Powerful gas or diesel engines permit full-shift operation with fuel to spare.

Pick the P&H welder you need from industry's most up-to-date line. Six models, skid- or wheel-mounted — with manual or electric starting. Write for Bulletin W-158.

316

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P&H welding equipment is manufactured and sold in Canada by REGENT EQUIPMENT MANUFACTURING CO., LTD., 455 King St. West • Toronto, Ontario, Canada.

For details, circle No. 31 on Reader Information Card

PERSONNEL

Officers Elected by Chicago Bridge

Arthus B. Horton was elected board chairman of Chicago Bridge & Iron Co. at a recent meeting of the board members in Chicago. The directors also elected the president, E. E. Michaels, chief executive officer; R. F. Hendren, executive vice-president and treasurer; and E. S. Fraser, manager of plants.

At an earlier meeting of the company's shareholders, John T. Horton was elected a director of the world-wide steel plate fabricating and construction firm.

Kalmeyer Elected President

Walter J. Kalmeyer has been elected president of the Leader Iron Works subsidiary of Standard Steel Corp., builders of chemical and petroleum processing equipment, and other industrial products.

Mr. Kalmeyer, a member of the parent company's board of directors, formerly was vice-president of manufacturing at Standard Steel's Los Angeles plant. Before joining Standard Steel in 1953, he was chief engineer and works manager of the Blaw-Knox division of Blaw-Knox Co., Pittsburgh, Pa. He is a graduate of the school of engineering of Carnegie Institute of Technology. Mr Kalmeyer is a registered professional engineer and a member of the AMERICAN WELDING SOCIETY.

Iapalucci Made Plant Manager

The appointment of Francis P. Iapalucci as plant manager of the Lake Erie Machinery Corp. at Buffalo, N. Y., has been announced by E. A. Rich, vice-president and general manager.

Mr. Iapalucci has had broad experience in both line and staff work in engineering, manufacturing and sales with Ford Motor Co. at Livonia, Mich.; Baldwin-Lima-Hamilton Corp. at Eddystone, Pa.; Jackson Products, Warren, Mich.; and Chrysler Corp. at Centerline, Mich.

Mr. Iapalucci, a member of the AMERICAN WELDING SOCIETY and this year's Chairman of the Philadelphia section, has been the author of several technical papers primarily on welding and plant operation. He is at present Vice-chairman of the Filler Metals Committee of ASTM and AWS and is Industrial Coordinator of the main Advisory Committee for Ordnance. He is and has been active on various committees including the Ordnance Specifications Committee, Fabrication Committee, Research Committee and the Cast Armor Metallurgical Advisory Committee of the Ordnance Dept. He is a member of the Executive Board of the American Ordnance Association and Chairman of the Combat and Tactical Vehicle Committee of that Association.

Mr. Iapalucci attended Wayne University in Detroit, Mich., and the Chrysler Institute of Engineering at Highland Park, Mich.

Francis P. Iapalucci

Truman J. Baldwin

J. P. Craven

Arthur B. Horton

Walter J. Kalmeyer

O. R. Carpenter

HANDY ALLOY DATA SHEET

HANDY & HARMAN ENGINEERING DEPARTMENT
82 FULTON STREET, NEW YORK 38, N. Y.

ALLOY LIST

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NAME	COMPOSITION PERCENTAGE Ag	Cu	Zn	Other	MELTING POINT °F	°C	FLOW POINT °F	°C	TROY OUNCES PER CU. IN.
EASY-FLO	50	15½	16½	(18 Cd)	1160	625	1175	635	5.0
EASY-FLO 3	50	15½	15½	(16 Cd-3 Ni)	1170	630	1270	690	5.0
EASY-FLO 45	45	15	16	(24 Cd)	1125	605	1145	620	4.9
EASY-FLO 35	35	26	21	(18 Cd)	1125	605	1295	700	4.9
SIL-FOS	15	80		(5 P)	1185	640	1300	705	4.5
SIL-FOS 5	5	88¾		(6¼ P)	1185	640	1300	705	4.4
TEC*	5			(95 Cd)	640	340	740	395	4.6
TEC-Z*	5		16.6	(78.4 Cd)	480	250	600	315	4.5
BRAZE 071 (SN #7)†	7	85		(8 Sn)	1225	665	1805	985	4.8
" TL	9	53	38		1410	765	1565	850	4.5
" ATT	20	45	30	(5 Cd)	1140	615	1500	815	4.6
" 202 (AT SPEC)†	20	45	35		1315	715	1500	815	4.7
" NE	25	52½	22½		1250	675	1575	855	4.7
" 251 (AE)†	25	57½	17½		1270	690	1625	885	4.7
" NT	30	38	32		1250	675	1410	765	4.7
" DT	40	36	24		1235	670	1415	770	4.8
" SS	40	30	28	(2 Ni)	1220	660	1435	780	4.8
" 404 (SS-5)†	40	30	25	(5 Ni)	1220	660	1580	860	4.7
" DE	45	30	25		1225	665	1370	745	4.8
" ETX	50	34	16		1250	675	1425	775	5.0
" 541 (4772)†	54	40	5	(1 Ni)	1340	725	1575	855	5.1
" 560 (ER)†	56	22	17	(5 Sn)	1145	620	1205	650	5.0
" 580 (EB)†	57½	32½		(7 Sn-3 Mn)	1120	605	1345	730	5.1
" RT	60	25	15		1245	675	1325	720	5.0
" 603 (RT-SN)†	60	30		(10 Sn)	1115	600	1325	720	5.2
" 630 (RSNI)†	63	28½		(6 Sn-2½ Ni)	1275	690	1475	800	5.1
" EASY	65	20	15		1240	670	1325	720	5.1
" 655 (RE-MN)†	65	28		(5 Mn-2 Ni)	1385	750	1560	850	5.2
" MEDIUM	70	20	10		1275	690	1360	740	5.1
" BT	72	28			1435	780	1435	780	5.2
" HARD	75	22	3		1365	740	1450	790	5.3
" 752 (TR #1)†	75		25		1300	705	1330	720	5.1
" IT	80	16	4		1340	725	1490	810	5.3
" 852 (85 Ag-15 Mn)†	85			(15 Mn)	1760	960	1780	970	5.1
PREMABRAZE 610	61	24		(15 In)	1155	625	1305	705	5.0

*A Solder – Not a Brazing Alloy. †Former Names

Space does not permit listing the many special alloys, formulated for a particular or unique application. Handy & Harman Brazing Engineers and Technical Service are always ready to work closely with you on metal joining problems and methods.

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This informative booklet gives a good picture of silver brazing and its benefits...includes details on alloys, heating methods, joint design and production techniques. Write for your copy.

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ELECTRICAL ENGINEER

The Welding Machine Division of the A. O. Smith Corporation has a career opening for an Electrical Engineer to work as a Project Engineer. The qualified candidate must have had previous transformer or rectifier design experience. This is not a "board job," but a real challenge for the future. For a personal and confidential interview, write:

R. J. Keller
A. O. SMITH CORPORATION
Box 584
Milwaukee, Wisconsin

Baldwin Appointed

Truman J. Baldwin has been appointed southeastern zone representative of Jackson Products, Air Reduction Sales Co., Warren, Mich.

A member of the American Society of Safety Engineers, and active in the Alabama chapter of the AMERICAN WELDING SOCIETY, he will cover North and South Carolina, Florida, Georgia, Tennessee and Alabama.

Craven and Carpenter Advance

J. P. Craven has been elected a vice president of the Babcock & Wilcox Co. by the board of directors, and placed in charge of the Boiler division's manufacturing department. Mr. Craven, who formerly was manager of the division's erection department, will make his headquarters at the Stirling Avenue offices in Barberton, Ohio. In his new position, he succeeds Paul H. Setzler, who has resigned.

At the same time, the board of directors elected O. R. Carpenter AWS assistant vice president, Boiler Division Manufacturing Department, reporting to Mr. Craven.

EMPLOYMENT OPPORTUNITY FOR ENGINEER

AWS is seeking an engineer to join Headquarters' Technical Staff as Assistant to the Technical Secretary.

Here is an opportunity—

The man we are seeking has initiative and imagination and is interested in becoming familiar with welding in all its aspects and for every type of application. Salary will be commensurate with qualifications and experience.

If interested in being interviewed for this position, send a resume* of your education, experience and personal background to

Technical Secretary
American Welding Society
33 West 39th Street
New York 18, N. Y.

* Will be held confidential.

RESEARCH POSITIONS OPEN

Plant and World Headquarters
Flushing, New York

Welding Research Center and European Headquarters
St. Sulpice, Switzerland

I am seeking important new members for our Welding Research Staff, and am particularly interested in meeting and discussing these opportunities personally with prospective candidates.

We have interesting positions available in our affiliated international Welding Research Center in St. Sulpice, near Lausanna, Switzerland. Applicants selected will work in our new ultra-modern research laboratories nearing completion, and which will be staffed by a large group of highly skilled technicians. The most up-to-date equipment will be available for our research staff, and every possible opportunity will be given to its members to develop their active ideas.

We need the following—

Welding Research and Development Metallurgists
Welding Process and Product Engineers
Formulation Development Chemists

These independent and challenging positions call for keen technical ability and an outstanding sense of responsibility.

Our organization is progressive both in its technical outlook and in its relationship with its personnel. We are well-known in the field and have been exceedingly successful in developing leadership in the welding industry. Many important projects are under study and in development stages, which offer constant challenge to our research group.

You are offered excellent remuneration and the opportunity for advancement. Applicants are requested to submit handwritten resumes, supplying information relative to work accomplished, personal data covering date and place of birth, educational background, languages spoken and written, as well as a recent photograph.

I will be interested in hearing from you, and would appreciate if you would address all replies directly to my attention.

René D. Wasserman, President
Eutectic Welding Alloys Corporation
40-40 172nd Street
Flushing 58, New York

VanHorn Promoted

Robert L. VanHorn was appointed regional sales assistant, Midwest region, of National Cylinder Gas Division of Chemetron Corp., it was announced recently.

Mr. VanHorn transfers to Chicago from Evansville, Ind., where he served as sales representative for the company during the past three years.

Revelt Is Appointed

The Lincoln Electric Co., Cleveland, Ohio, announces that Jean J. Revelt AWS has been named public relations assistant. Mr. Revelt, an engineering graduate in physics from Case Institute of Technology, has held the position of welding engineer in the Milwaukee District for the past 8 years.

His technical training and field experience will now be available to the welding industry through his participating in Lincoln's educational and technical publishing activities.

EMPLOYMENT SERVICE BULLETIN

Services Available

A-727. Design and Welding Engineer. Eight years' experience in design of resistance welding heads, automatic welding equipment, and tungsten-arc welding of light gage metals. Also design of welding tools, hydraulic and pneumatic equipment. Prefer Boston, Mass., area.

A-728. Welding Technician. Thirty-four years' experience, all metals and methods. Was operator, group leader, instructor, technician and welding engineer. Heavy back-ground in aluminum and stainless, including jet engines. High school, some college, and courses in metallurgy and welding. Desire position as technician, instructor, liaison, supervisor, trouble-shooter, etc. Good health. Married. Will relocate or travel. Salary commensurate.

A-729. Welding Engineer. Thirty-two years of age. B.S.E.E. Six years' experience in welding. Heavy experience in selling, writing welding procedures and production planning. Familiar with all major welding processes in a wide range of application from aircraft production to heavy equipment. Experienced in heat treating, furnace brazing and instrumentation. Will relocate.

New Hi-Impact Plastic Insulated
Panel Receptacles and Mating Plugs

Now, you can make fast, positive power connections to any metal panel or housing without special insulating materials. Simply punch out a hole and insert a Cam-Lok self-insulated Receptacle! Uses standard electrical lock-nuts, affords "dead-front" protection. Push in and twist Cam-Lok mating Plug and you've made a locked connection, which can be released quickly.

New Cam-Lok Receptacles eliminate costs of special insulating panels and reduce assembly time. Patented, high-pressure contact assures minimum resistance and heating.

Cam-Lok has a complete line of Receptacles and Plugs in many sizes and designs. Standard and special purpose Power Distribution Connections are available. Write today for new Bulletin No. 301.

"Dead Front" design for fast direct mounting on . . .

- ELECTRICAL DISTRIBUTION PANELS
- SWITCHGEAR
- BUS DUCT
- JUNCTION BOXES
- WIREWAY or any electrical cubicle

cam-lok DIVISION

EMPIRE PRODUCTS, INC.
P.O. BOX J-98
CINCINNATI 36, OHIO

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OBITUARY

George W. Lamb

George W. Lamb, nationally known civil engineer, died at his home on Nov. 28, 1959. He had a long and distinguished record as a civil engineer, bridge designer and structural consultant.

Born in Leavenworth, Kan., in 1900, he graduated from the University of Kansas in 1926 with a degree of Civil Engineer and worked his way up to Bridge Engineer of the State Highway Commission of Kansas. During World War II he was associated with the Missouri Valley Bridge and Iron Co., engaged in building welded ships. Subsequently he served as District Engineer for the AISC until 1954 when he became bridge engineer for Howard, Needles, Tammen and Bergendoff, in charge of bridge design and construction for the Kansas Turnpike and 18th St. Expressway in Kansas City.

At the time of his death, Mr. Lamb was engaged in private practice as a structural consultant in Topeka. An outstanding pioneer in the use of arc welding for bridge construction, he was a well-known member of the AMERICAN WELDING SOCIETY serving on the Board of Directors, various technical committees and the Fatigue Testing Committee of the Welding Research Council. He was past-president of the Kansas Chapter of ASCE and past-director of the Kansas Engineering Society. The author of a number of outstanding technical articles, he was listed in *Who's Who in Engineering* in 1948.

George W. Lamb

Ellsworth L. Mills

Ellsworth L. Mills

Ellsworth L. Mills, vice-president and a director of the Bastian-Blessing Co., Chicago, died suddenly of a heart attack on Sunday, Dec. 6, 1959. He was 72 years old.

Mr. Mills was known as "The Colonel" to business associates, customers and friends in the liquefied petroleum and high-pressure gas industries served by his company throughout the world. At the time of his death he had served over 20 years as a vice-president and director of the Liquefied Petroleum Gas Assn. which he was instrumental in founding, and was also serving as a vice-president and director of the LP-Gas Council.

In 1953, he received both the LPGA Distinguished Service Award, and a Kentucky Colonelcy.

Mr. Mills was a founding director of the AMERICAN WELDING SOCIETY, past president and director of the International Acetylene Assn. and past-president of the Gas Products Assn.

He was born in Denver, Col., May 13, 1887, and was graduated with a Bachelor of Science degree in Civil Engineering from Cooper Union Institute in 1910. In 1919 he joined Bastian-Blessing as sales manager of the one man department which was to become the Rego Division.

Mr. Mills is referred to, very often, as the "father" of the Liquefied Petroleum Gas Association and served on many of its committees. He served on the LP-Gas Council as vice-president and LPGA representative on its Board of Directors.

His other industrial memberships included the Army Ordance Assn., the National Security Industrial Assn., the Agricultural Ammonia Institute and the Compressed Gas Assn.

Mr. Mills leaves his widow, Mary Roberts Mills, three daughters and two sons.

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THERE IS AN EASIER WAY
I.E.C.O.
with an INDEPENDENT
Model "200"
Valving Machine
Insertion or removal of Gas Cylinder Valves or similar threaded units, such as I.E.C.O. Test Plugs used with Hydrostatic Gas Cylinder Testing Equipment, is done by a simple turn of a Control Knob which directs the rotation of the Valve Wrench. The machine can quickly be adjusted for cylinders of diameters from 3 through 16 inches and heights of 10 through 60 inches. Available for 110-220 or 440 volt installation.
The Model "200" Valving Machine is compact — requires only 8 square feet of floor space.
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New Literature

Two New Publications Released by AWS

The AMERICAN WELDING SOCIETY announces the availability of two new publications.

Welding Nuclear Power Piping

One of these, entitled *Welding Nuclear Power Piping*, is the first publication on welding ferrous materials for nuclear-power piping operations issued by AWS. The 20-page report was compiled by nuclear-power experts and represents their combined knowledge of the best methods and procedures to be used in this new industry. An AWS Committee spent two years examining methods and practices and sifting information from nuclear-power engineers before compiling the report.

The contents include welding procedures, detailed sketches of operations, joint design—angles and dimensions, quality control, qualification of procedures, qualification of welders, and inspection methods.

Titanium Welding

The second booklet, *Titanium Welding*, is a 24-page report explaining the best methods for welding titanium piping and tubing by the gas tungsten-arc process. A complete description is given, from an explanation of the welding process to the selection of electrode filler metal.

Many people and many companies contributed to the report. The information was obtained from current welding literature, company files, research laboratories and colleges. The material was carefully examined by an AWS Committee and approved by acknowledged experts in the field.

The contents include process, power supply, and filler metal; titanium grades, joint design and preparation, cleaning; gas shielding, welding techniques; heat treatment; weld-quality tests.

●

Copies are available from the AMERICAN WELDING SOCIETY, Dept. T., 33 W. 39th St., New York 13, N. Y. Price $1.50 per copy.

Induction Stress Relieving

A three-page folder, which illustrates and describes the use of portable 400-cycle induction-heating equipment for stress relieving welded joints, is offered by Hobart Brothers Co., Troy, Ohio. The folder explains the principle of high-frequency induction heating and answers many questions about its use for stress relieving welded joints. A number of unusual stress relieving jobs, which were accomplished with 400-cycle high-frequency induction-heating equipment, are also illustrated and described.

For your free copy, circle No. 51 on Reader Information Card.

Principles of Welding Preheat

Successful welding of low-alloy high-tensile steel and other alloy steels with the aid of preheat is explained in a 40-page "Guide to Preheat" issued by J. B. Nottingham & Co., Inc., 441 Lexington Ave., New York 17, N. Y.

Physical and chemical changes that take place in these "problem" steels during and immediately after welding are outlined. Cracking, porosity and other weld defects can result from these changes unless they are controlled by the use of preheat.

Properly applied, preheat makes it practical to produce quality welds, even on hard-to-weld steels. The publication explains how preheating with electric strip heater systems, made up of interchangeable, reusable units, is successful from the standpoint of simple, economical application as well as the quality of the resulting welds.

For your free copy, circle No. 52 on Reader Information Card.

Flame-cutting Pantograph

An eight-page catalog introducing the Linagraph, a newly designed flame-cutting machine, has just been issued by Air Reduction Sales Co., Inc., 150 E. 42nd St., New York 17, N. Y. The catalog describes the advanced design, construction and operation. Liberally illustrated with photographs, it explains the principal features of this automatic gas-cutting machine such as centralized operator control, pantograph design, motorized torches and its adaptability to various tracing devices.

For your free copy, circle No. 53 on Reader Information Card.

Physical Equivalents of Cryogenic Fluids

A folding pocket card (form 1341) presenting in tabular form the physical property equivalents of some cryogenic fluids is now available from Distribution Dept., Linde Co., Division of Union Carbide Corp., 30 E. 42nd St., New York 17, N. Y.

The card gives boiling and melting points; critical temperatures and pressures; volume, mass, and thermal equivalents; and conversion factors. The cryogenic fluids treated are those most useful to engineers in the chemical and missile industries.

For your free copy, circle No. 54 on Reader Information Card.

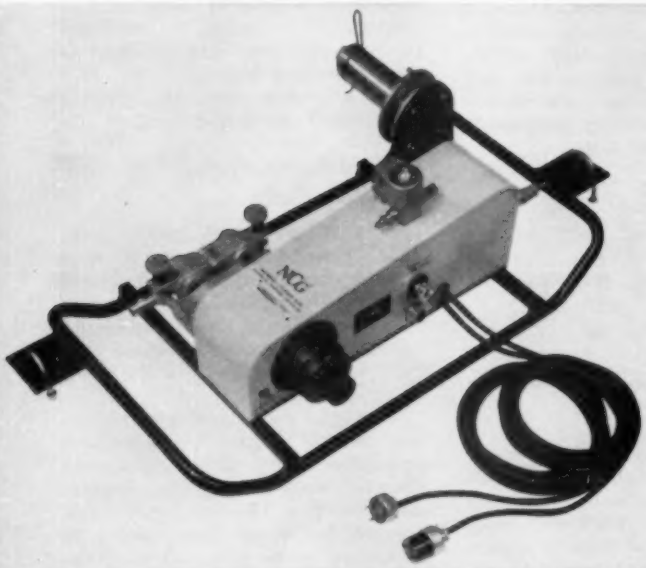
Welding Methods for Girth Seams

A bulletin describing what is known as Circomatic equipment for automatically welding girth seams on field-erected storage tanks is available from the Arcos Corp., 1500 S. 50th St., Philadelphia, Pa.

The bulletin explains this new process utilizing visible arc, CO_2-shielded welding apparatus supported by a "saddle-bag" cab which rides around the top edge of the tank plates The illustrated four-page folder, which doubles as an instruction sheet, contains detailed information about preparing plates

New NCG® Consumable

Newly designed, incorporating features that were developed to meet field requirements, the new WC-1 Welding Control Unit and the AM-1 Torch have advantages you should know about. Designed for Automanual* consumable electrode welding processes using Argon, Helium or Carbon Dioxide as a shielding gas, they provide maximum versatility and economy.



WC-1 Welding Control with Wire Drive

Double gate wire drive unit—1/10 HP Motor
Wire (3/64" to 3/32") feed rate: 55"—500" per min.
Clears 18" manhole—Weighs 55 lbs.
Easy to control
Sturdy, simple electrical components

AM-1 Torch

Unitized design—molded as one unit
Light weight—hand balanced
Delivers electrode and shielding gas to the arc
Complete package—all cables and hoses supplied
On-off switch on handle
Water-cooled cup

For details, circle No. 35 on Reader Information Card

Electrode Welding Equipment

DUAL SHIELD...

the carbon dioxide welding process that saves

The DUAL SHIELD* process is being used successfully by many plants, and the scope of its application, ranging from plain-carbon to low-alloy high-tensile steels, is constantly increasing. The oxidizing, scavenging and slag-forming flux compounds, the greater amount of weld metal deposited with better penetration, the higher welding speeds, the combination of inexpensive CO_2 and the flux compounds to provide arc stability, and the better weld quality obtained are all factors that contribute to the wide acceptance of DUAL SHIELD welding. Many are realizing good savings in reducing weld time and costs in spot welding and in foundry repair welding.

Four flux-cored electrodes are used with this process:

No. 110—A single-pass electrode for plain-carbon steels with a maximum carbon content of 35 points

No. 111A—A multipass electrode for the same steels welded by No. 110.

No. 150 and 151—Multipass electrodes for high-tensile low-alloy steels.

Since the cost of welding is a major factor in your operations, the DUAL SHIELD welding process and the new NCG WC-1 Welding Control Unit and AM-1 Torch can have an important bearing on your future profits. This new equipment is reasonably priced and the DUAL SHIELD process will cut production costs. It has for others and will for you.

Write today for more information...
Six page bulletin detailing
DUAL SHIELD Welding Process: NH 137.

NATIONAL CYLINDER GAS
DIVISION OF CHEMETRON CORPORATION
840 North Michigan Avenue,
Dept. E-1B, Chicago 11, Illinois

CHEMETRON

NCG offices and authorized DUAL SHIELD *distributors are located in all principal cities.*
Consult the yellow pages for the office nearest you.

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and operating the equipment as well as a table giving edge preparations, passes, currents and travel speeds required to weld plates from $^1/_4$ to $1^1/_2$ in. thick.

For your free copy, circle No. 55 on Reader Information Card.

30th Anniversary Issue

Magnafacts, a 12-page bulletin published by Magnaflux Corp., Subsidiary of General Mills, 7300 W. Lawrence Ave., Chicago 31, Ill., contains the story of the 30-year growth of this company, in the Fall 1959 issue. A short biography of the founder is included with articles showing the application of nondestructive testing methods. The acquisition of the company by General Mills is described.

For your free copy, circle No. 56 on Reader Information Card.

Cryogenic Equipment

A complete line of cryogenic equipment to store, handle and transport low-temperature liquid gases is described in a new 16-page bulletin, offered by Standard Steel Corp., 5001 S. Boyle Ave., Los Angeles 58, Calif., or Industrial Park, Lowell, Mass.

The two-color publication presents photographs and typical specifications for Standard-Cambridge customer stations, bulk storage vessels, truck transports, aluminum transport trailers, and low-, medium- and high-pressure liquid pumps. Also described and pictured are Standard-Cambridge space vehicle fueling vessels and special cryogenic systems.

For your free copy, circle No. 57 on Reader Information Card.

Heat Loss in Welding Cable

Control of heat losses caused by faulty connections in welding cables is the subject of a 4-page folder issued by Tweco Products, Inc., P. O. Box 666, Wichita 1, Kan. Various defects are listed which cause man-hour as well as power losses in copper and aluminum cables. A number of check points are listed and suggestions are made for the correction of some of the common abuses. For other defects, the value of Tweco connection devices is made apparent.

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BANTAM
IRON WORKER

THE ONLY IRON WORKER OF ITS KIND ON THE MARKET TODAY

No Grinding Necessary After Cut. One Stroke Cycle Clutch Operated by Hand or Foot.

The Bateman "Bantam" cuts 2" x 2" x ¼" angles and ¼" x 4" flats. Standard punches will fit this machine. The Coper will cope 1¼" through ⅛" material. It will punch ½" hole through ¼" material. With the clutch open, the Bantam will make 44 strokes per minute. It is made of high-grade cast iron, with the clutch, pin and dog made of hardened steel. The blades are made with tool steel. It is powered with a fly wheel and gear drive, and uses a small ¾ hp motor, 1750 rpm.

Bateman Bantam with punch ... $575.00
Shear only ... $495.00
Shipping wt. 750 lbs.

BATEMAN FOUNDRY & MACHINE
MINERAL WELLS, TEXAS

For details, circle No. 44 on Reader Information Card

Temperature Indicators

Tempil° Corp., 132 W. 22nd St., New York 11, N. Y., has issued a revised pamphlet to include the new temperature ratings of products developed during the past year. Eighty ratings of Tempilstiks° and of Tempilaq° are listed from 113° to 2500° F in systematically spaced intervals. Tempil° Pellets are listed in 90 temperature ratings up to 2700° F.

For your free copy, circle No. 60 on Reader Information Card.

Application of Welding Symbols

Designer's Guide for Welded Construction has been revised by the Lincoln Electric Co., Cleveland 17, Ohio, to include recent revisions in the AWS Standard Welding symbols. Bulletin Number 1100.1 contains charts and illustrations providing information on the application of welding symbols and other basic design data on welds.

For your free copy, circle No. 62 on Reader Information Card.

The Perfect Welding Mates
TEC SPOT GUN

TEC

This TIG spot welding tool perfectly bridges the gap between resistance welding and TIG arc welding. The TEC Spot Gun has been designed to increase production output and replace expensive spot welding operations. The lightest weight, most compact spot gun ever made, it comfortably fits the operator's hand. Weld up to, and including ⅛" thickness to any size stock and in any joint design. There are no movable parts to wear or replace, permitting maintenance free operation. Touch starting is replaced by high frequency arc starting, reducing electrode waste and work contamination.

LOCATORS OF ANY DESIGN AVAILABLE

TEC SPOT CONTROL

This perfect welding mate for the TEC Spot Gun, converts any DC power source into a new TIG spot welding machine. A choice of preset welding times can be selected at the gun itself. The TEC spot control unit is light and compact, with easy to read controls. It is the only control unit of its kind. This portable TEC spot control unit can easily be connected to any DC power source.

Write NOW for full information on the TEC Spot Gun and other Superior Visuweld Equipment
TEC TORCH CO., INC. 300 PATERSON AVENUE CARLSTADT, NEW JERSEY

For details, circle No. 36 on Reader Information Card

Abstracts of Current PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D.C.

2,902,755—METHOD OF MAKING BRAZING MATERIAL—Albert Edward Salt, Edgbaston, and Edwin Albert Taylor, Birmingham, England, assignors to Imperial Chemical Industries, Ltd., London, England, a corporation of Great Britain.

In this novel method of making brazing material, a nickel tube having a specified weight is mixed with specified quantities of titanium and copper powders and then the tube is reduced to consolidate the powder and provide a brazing material having a composition of 62% titanium, 29% nickel and 10% copper.

2,903,554—CUTTING AND GOUGING TORCH—Myron D. Stepath, Lancaster, Ohio, assignor to Arcair Co., Lancaster, Ohio, a partnership.

In this electric arc-gas jet cutting and gouging apparatus, an elongate hollow housing is provided. Electrode supporting means are present within the housing and they have an orifice extending therefrom for directing a gas jet longitudinally along a positioned electrode. Means connect to the housing to supply electric current to the electrode and gas under pressure to the gas passageway and orifice provided.

2,903,558 — ELECTRIC - WELDING METHOD—William E. Smith, Detroit, Mich., assignor to Midland-Ross Corp.

Smith's welding method is for securing a pair of members together when they are in overlapped relation. Initially an arc is created between an electrode and the outer one of the layers in the overlapped portion to melt through the outer layer and at least a portion of the other layer to form a molten seam of metal. Simultaneously a gas is directed against the molten seam at a pressure sufficient to create a force to maintain the molten seam in position until solidified.

2,903,559—TORCH FOR ARC WELDING—Bernhard Wempe, Mullheim, Baden, Germany.

The patented arc-welding apparatus includes two electrodes arranged for producing an electric arc therebetween. Three annular nozzle means are positioned in concentric relation around the electrodes so that a welding gas can be supplied to the first welding nozzle, a protective gas can be supplied to the second nozzle and carbon dioxide or equivalent gases can be supplied to the third nozzle means.

2,903,560—COOLED BURNER DESIGNED FOR SHIELDED-ARC WELDING AND CUTTING OF METALS—Alfred Barfuss, Sous-Geronde, Sierre, and Willy Welz, Glattbrugg, Zurich, Switzerland, assignors to Verwaltungsgesellschaft der Werkzeugmaschinenfabrik Oerlikon, Zurich-Oerlikon, Switzerland, a Swiss Company.

A specialized unit is disclosed in this patent in which an electrode is operatively carried in a metallic jacket so that coolant means can be flowed around the electrode positioning means. A gas nozzle also is provided in the burner unit.

2,903,561—WELDING APPARATUS—Clair M. Rively, White Meadow Lake, N. J., and Eric L. Midgley, Salem, Mass., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pittsburgh.

A specialized machine for welding a base pin of a base for the opposite ends of a fluorescent lamp to a lead wire that protrudes from the base pin is disclosed in the present patent. By the machine, the fluorescent lamp is moved successively to several different work stations where different preparatory and finally a welding action are performed.

2,903,563—STUD-WELDING GUN—Eelke Herman Etteman, Utrecht, and Jan Anthonie van Bergen, Eindhoven, Netherlands, assignors, by mesne assignments to North American Philips Co., Inc., New York, N. Y., a corporation of Delaware.

The patented stud-welding gun includes a frame having a portion adapted to be positioned on a member to which a stud is to be secured. A supporting member is slidably mounted on the frame and includes means for adjustably supporting a stud. A clamping means is provided to secure a stud positioning member in adjustable relation to the supporting member.

2,903,564—METHOD OF PROVIDING A WEAR-RESISTANT SURFACE—Laurence H. Carr, Homewood, Ill., assignor, by mesne assignments, to the Edward Valves, Inc., East Chicago, Inc., a corporation of Delaware.

Carr's patent is on a method of assembling a relatively thin hard metallic element having a continuous uniformly beveled face upon a member having at least two continuous projections capable of simultaneous continuous contact with the beveled face to provide a surface upon the member of a different hardness characteristic from that of the member. In the method, the members are brought into high pressure engagement between the element face and the said projections and a high amperage electrical current is passed between the metallic element and the member to fuse them together.

2,903,566—MOUNTING FOR A WELDING HEAD IN A WORK-FABRICATING MACHINE—Ernie L. Launder, Montebello, Allen W. Loudon, Downey, and Max Frederick, Jr., Whittier, Calif., assignors to H & L Tooth Co., Montebello, Calif., a corporation of California.

In this patent, a mounting for a welding head in a fabricating machine is provided and the head includes a rod feeding means directing the rod on an axis angularly related to and intersecting an axis of rotation at the point of weld. A spindle is mounted to turn on the axis of rotation and it carries the welding head. Power supply means that connect to the welding head include a slip ring and brush assembly at the spindle, and other members are present adapted to turn the spindle a predetermined amount at predetermined times during each cycle of operation of the machine.

2,903,567 — ARC - WELDING APPARATUS—Julian A. Piekarski and John A. Russell, Milwaukee, Wis., assignors to A. O. Smith Corp., Milwaukee, Wis., corporation of New York.

This patent is on an arc-welding hand gun for simultaneously directing a consumable electrode and a shielding gas so as to sustain a weld arc. An electrically insulated casing or frame is provided that has a hollow body portion and has a depending handle portion. Other means are present so that a water inlet and a water outlet, and a gas inlet and a welding cable can all be engaged with the frame. An electrode contact tube having a tube-like electrode guide therein is associated with the insulated casing.

2,903,568—ELECTRODE HOLDER—Martin Wells, Pasadena, Calif.

Wells' welding rod holder includes first and second levers hingedly connected intermediate their ends and having front jaws for gripping a welding rod. A cable connects to the rear end of one of the levers while an insulator is slidable onto the first lever. Spreader means between the rear ends of the levers are provided to cause the jaw elements to swing toward each other and grip the rod therebetween. The spreader means secures the insulator in position.

2,904,668—WELDING OF METAL STRIPS AND TUBING—Wallace C. Rudd, Larchmont, and Robert J. Stanton, Brooklyn, N. Y., assignors to Magnetic Heating Corp., New Rochelle, N. Y., a corporation of New York.

In this welding method, a seam is to be provided extending along opposed edges of two relatively thick elongated metal portions. Initially these portions are advanced past the weld point and the edges are firmly retained together as they reach the region of the weld point. High frequency current is conducted onto the upper surface of the metal portions adjacent the proposed seam and in advance of the weld point to maintain the flow of current to heat up the edges to welding temperature when the edges reach the weld point. The flow of current is caused to extend over substantially the full depth of the edges by maintaining near the undersurfaces of the metal portions a mass of nonmagnetic highly conductive material that effectively decreases the reactance of the current paths on the lower portions of the edges, as compared with the reactance for the high frequency for the upper portions of the edges.

2,904,669 ARC-CURRENT CONTROLLING APPARATUS FOR WELDERS' HELMETS—George F. Toebe, Chippewa Falls, Wis.

This patent covers, in combination with a welding helmet, the provision of certain circuit control and opening means operatively connected to a movable shutter in the welding helmet so that when a weld rod is lifted from the work, the main switch in the arc welding circuit is opened, and a solenoid then can move the eye protective shutter to an inoperative position.

2,905,802—CATHODE TAB FEED AND WELDING MACHINE—Henry W. Roeber, Emporium, Pa., assignor, by mesne assignments, to Sylvania Electric Products Inc., Wilmington, Del., a corporation of Delaware.

A specialized material feeder, cutter and welder apparatus is covered by the present patent. In this apparatus, a special support means is provided and the feeding means, cutter and welder are adjustable so that the welder can reach any part of an object on the support and located in a horizontal plane.

2,905,803—NUT LOADING AND WELDING MACHINE—William A. Brady, Jr., Warren, Mich., assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

Brady's patent relates to an automatic nut loading and projection welding machine. The machine includes a motorized hopper for containing and continuously feeding sheet metal nuts to be welded into welding positions on a metal sheet. A pair of oppositely disposed and relatively reciprocal electrodes are movable into engagement with a nut on the sheet for resistance welding action.

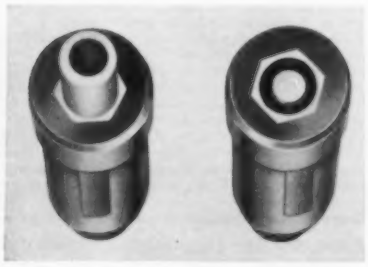
2,905,804—MAGNETIC - FORCE WELDING MACHINE—William M. Wakeley, Milwaukee, Wis., assignor to Acro Welder Mfg. Co., Milwaukee, Wis., a corporation of Wisconsin.

This patented welding machine includes an electrode mounted on a frame by special moving means and means connecting thereto so that the electrode can be moved toward and away from the work. Another member is present to exert a supplementary force on the electrode and the movement means for the electrode permit disengagement of the electrode from the moving means during application of this supplementary force.

New Products

Patented Cable Connector

A welding cable connector that won't overheat or arc, and joins securely with a twist of the wrist, is reported by Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 46, Wis., producer of bronze electrodes, filler rod and wire.



A patented eccentric-locking or wedging action is said to provide an efficient electrical contact, preventing overheating. Normal wear increases the contact area, extending connector life.

For details, circle No. 101 on Reader Information Card.

Self-fluxing Brazes

A line of self-fluxing Nicrobraz brazing alloys for high temperature service applications is now available from Stainless Processing Division, Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich. The alloys are said to contain a vaporizing flux which permits brazing difficult alloys (such as aluminum and titanium bearing metals) in hydrogen and argon atmospheres and are available in the following Nicrobraz designations: Standard, 30, 50, 60, 130, 150 and LM, with a "W" suffix. For example, Nicrobraz 50 becomes Nicrobraz 50-W in the new self-fluxing line. Addition of the vaporizing flux does not change alloy specifications or properties and has no effect on joint properties.

For details, circle No. 102 on Reader Information Card.

New Line of A-c Arc-welding Machines

A line of M&T Murex AC industrial arc welding machines in 200- to 500- amp capacities, for heavy-duty production welding, has been announced by Metal & Thermit Corp., Rahway, N. J. Designated Types M20 to M50, these units are designed to NEMA standards for heavy-duty industrial welding, and are reported to provide optimum arc characteristics and stability over a wide variety of electrode types and sizes.

Dual coil transformer design provides balanced wave output for a smooth, stable arc under all welding conditions. A full 75-v open circuit is provided for instant arc starting. Current control is adjustable continuously through the range of each unit. Forced air cooling protects the transformer against extra-heavy loads.

For details, circle No. 103 on Reader Information Card.

Brazing Alloy

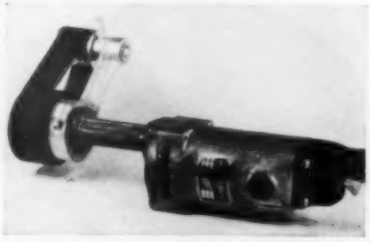
Among recent developments, one by the Superweld Corp., North Hollywood, for a high-temperature, controlled-atmosphere brazing alloy, has been disclosed. The new material is composed of copper, nickel. and boron and has appreciably greater strength than the standard copper brazing alloys heretofore used commercially.

The new alloy was further described as being particularly useful in progressive step-brazing techniques. This procedure allows the prefabrication of brazed components and the subsequent assembly into a composite unit by furnace-brazing methods.

For details, circle No. 104 on Reader Information Card.

Belt Grinding Attachments

Two belt grinding attachments are reported available for both angle and straight-wheel type portable grinders of any make powered by either air or electricity according to the Nedco Co., 27 Jones Rd., Waltham 54, Mass.

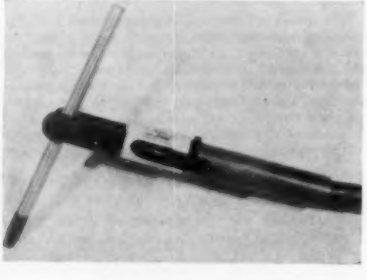


Conversion is said to take only minutes and together with the quick-change belt feature, the attachments greatly increase the variety of work per tool.

For details, circle No. 105 on Reader Information Card.

Air-carbon-arc Cutting Torch

A heavy-duty manual Arcair torch is available to industries whose work requires the use of the large sized electrodes, $^{5}/_{8}$ and $^{3}/_{4}$ in., for fast removal of large areas of metal. Like other torches in the Arcair line, it uses the heat of an electric arc to melt metal, and a stream of compressed air blows it away. According to the manufacturer, Arcair Co., Lancaster, Ohio, the H-6 can be used on any application requiring high currents for maximum speed in metal removal, but one of its primary purposes is casting conditioning in foundry cleaning rooms.

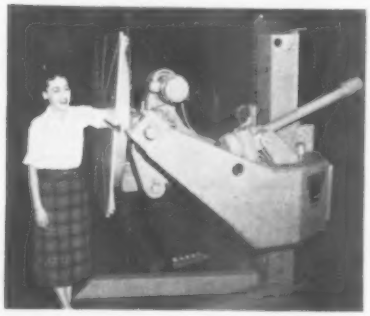


Said to be insulated to insure maximum life, the forward section of the torch handle and the positionable head both have a protective sleeve of silicone glass laminate. A special rubber boot provides a safety cover for the electrical connection on the end of the torch concentric cable.

For details, circle No. 106 on Reader Information Card.

Welding Positioners

Formerly available only on special order, a hole through the table and table spindle is now standard on all P&H welding positioners of capacities from 500 to 10,000 lb,



according to Harnischfeger Corp., Milwaukee 46, Wis. This greatly facilitates the use of gas lines for backing and preheating, and air lines for pneumatic clamping.

For details, circle No. 107 on Reader Information Card.

Safety Spectacles

"Unispec Twins" are safety spectacles made by Glendale Optical Co., 600 W. Merrick Rd., Valley Stream, N. Y. Said to fit every face, two models cover five bridge sizes.

Also offered by the same company is a welders' goggle made to fit over glasses and which utilizes angled lenses. Called the "Seesall Cover-Spec Goggles," the wearer is said to obtain a clear view of the entire work area, without blind spots, by a slight tilt of the head, The angled lens design is said to eliminate neck and shoulder fatigue.

For details, circle No. 108 on Reader Information Card.

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For details, circle No. 41 on Reader Information Card

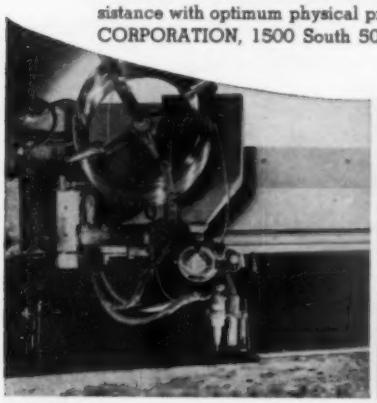
Job Report Courtesy of
Alco Products, Inc., Schenectady, N. Y.

Nuclear pressure vessel stainless clad at low cost

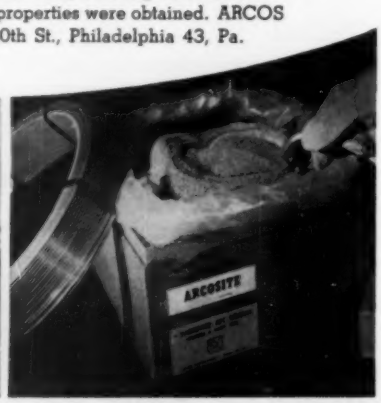
USE ARCOS

STAINLESS WIRE and BONDED FLUX

This "barrel" is one of several that comprise a nuclear pressurizer to operate under highly corrosive conditions. To reduce costs, Alco Products forged the shell of ASME A-336, 2—4 inch thick manganese molybdenum steel and clad the inside with stainless. The illustration shows the second pass overlay which was made by submerged arc using Arcos Chromenar K-LC (Type 308) bare wire and Arcosite S4 flux. Lower cost, and high corrosion resistance with optimum physical properties were obtained. ARCOS CORPORATION, 1500 South 50th St., Philadelphia 43, Pa.



Bare Wire

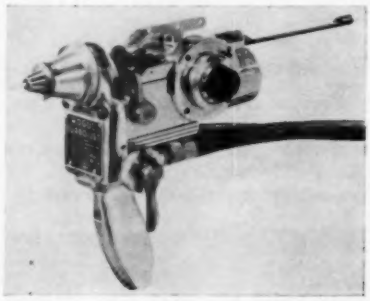


Arcosite Flux

For details, circle No. 42 on Reader Information Card

Ceramic Spray Gun

A high-pressure, high-velocity, spray gun for applying ceramic coatings to metal and other nonporous surfaces has recently been announced by Metallizing Co. of America, 3520 W. Carroll Ave., Chicago 24, Ill., manufacturers and



designers of metal spray equipment. The ceramic spray gun is said to apply an even, fine mist of protective coating that can be built up to exacting, specified thicknesses of aluminum and zirconium oxides, and zirconium silicate.

Benefits of the ceramic coatings are varied, including thermal, friction and corrosion protection.

For details, circle No. 109 on Reader Information Card.

Spot-welding Electrodes

Bren Weld Corp., 5114 Third Ave., Brooklyn, N. Y., manufacturers of the Model G Arc Spot Weld Gun and Model No. 100 Power Supply, announce that stainless steel electrodes, to be used with this equipment, are now available for immediate shipment.

For details, circle No. 110 on Reader Information Card.

Custom Design Offered in Gamma Radiography

A line of custom-designed equipment for the use of very strong radioactive sources is offered by Radiation Engineered Services, Lafayette and Water Streets, Norristown, Pa.

Gamma-ray machines ranging from small hand-carried cameras for field work to units containing thousands of curies for safe, automatic operation are said to be within the scope of this company. In addition, gamma irradiators for studying the chemical and physical effects of radiation on various materials, products and processes is offered. Monitoring devices are designed for use with the above equipment.

For details, circle No. 111 on Reader Information Card.

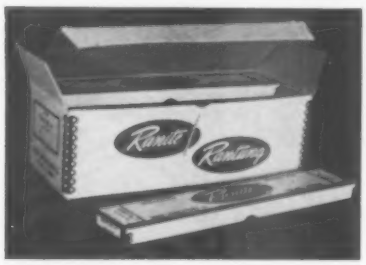
Small Package Units for Brazing and Soldering

Many problems are said to be solved simultaneously by All-State Welding Alloys Co., 249-55 Ferris Ave., White Plains, N. Y., with small size packages of its most popular items. Separate display boxes feature low melting silver brazing rod (Siltube), phosphor-copper brazing rod (Phostube), and silver-bearing phosphor-copper brazing rod (Silver Phostube). These rods are all packaged in tubes of transparent, flexible, shatterproof plastic. Solders, fluxes and other items are similarly packaged.

For details, circle No. 112 on Reader Information Card.

Newly Packaged Electrodes

Rankin Manufacturing Co., P. O. Box 631, Alhambra 2, Calif., announces a convenient package for three of its welding rods. Ranite



No. 4 acetylene rod, and Rantung acetylene and electric rods will appear in 5-lb packages and are available in 50-lb shipping cartons.

For details, circle No. 113 on Reader Information Card.

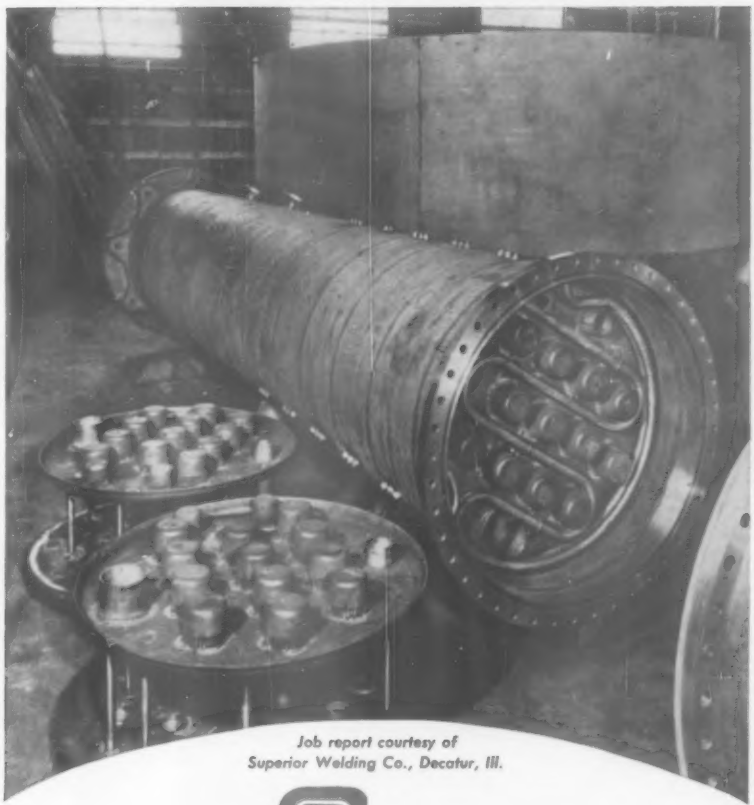
Method for Dressing Resistance-welding Rolls

A production bugaboo and cost thief on many welding jobs may be licked for good by a new automated roll-dressing method. Engineers at National Electric Welding Machines Co., Bay City, Mich., who designed the method for a special seam-welding machine, report it can be used with equal success on machines assigned to jobs calling for intermittent welding or requiring periodic dressing.

Lower inventory in expensive copper alloy spares, longer roll life and fewer roll changes are among the benefits claimed for the method which reduces dressing to a maintenance function. The system mounts on the welding machine itself and uses tried-and-tested lathe cutting to remove buildup.

For details, circle No. 114 on Reader Information Card.

When corrosion is a threat to the life of Stainless Welds



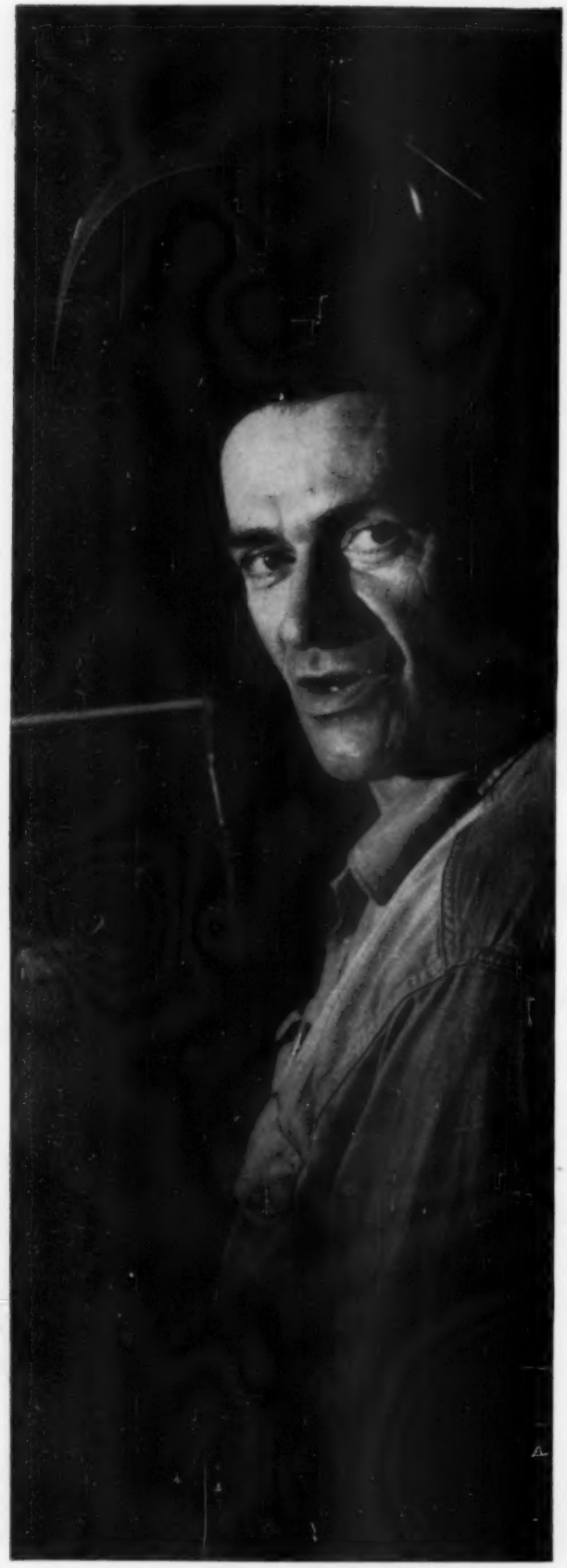
Job report courtesy of Superior Welding Co., Decatur, Ill.

WELD WITH ARCOS

STAINLESS ELECTRODES

This is a nitric acid absorption column for the chemical industry. The shell and flanges of solid 304 ELC stainless were welded with Arcos CHROMEND 19-9 Cb Electrodes to resist chemical attack at 150 p.s.i.g. and 300°F. Arcos CHROMEND K-LC Electrodes were used for welding the bubble caps and coil clips. Together, these two Arcos Electrodes proved the point: there's no substitute for quality weld metal when long uninterrupted service is essential. ARCOS CORPORATION, 1500 South 50th Street, Philadelphia 43, Pa.

For details, circle No. 43 on Reader Information Card



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Jetweld Low-Hydrogen Electrodes,
you'll agree with us when we say,

There's no such thing as hard-to-weld steel!

Sulphur-bearing steels that normally can't be welded without porosity—

High-tensile steels that are susceptible to underbead cracks and microcracks—

Heavy plate on which welds often crack—

All are welded easily and successfully, in any position, with Jetweld Low-Hydrogen rods.

An iron powder coating makes for fast, smooth operation.

And three tensile classifications handle every Low Hydrogen application.

Jetweld LH-70, E-7018,
Jetweld LH-90, E-9018-G,
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Try them for the very finest physical properties and on steels you thought were tough to weld.

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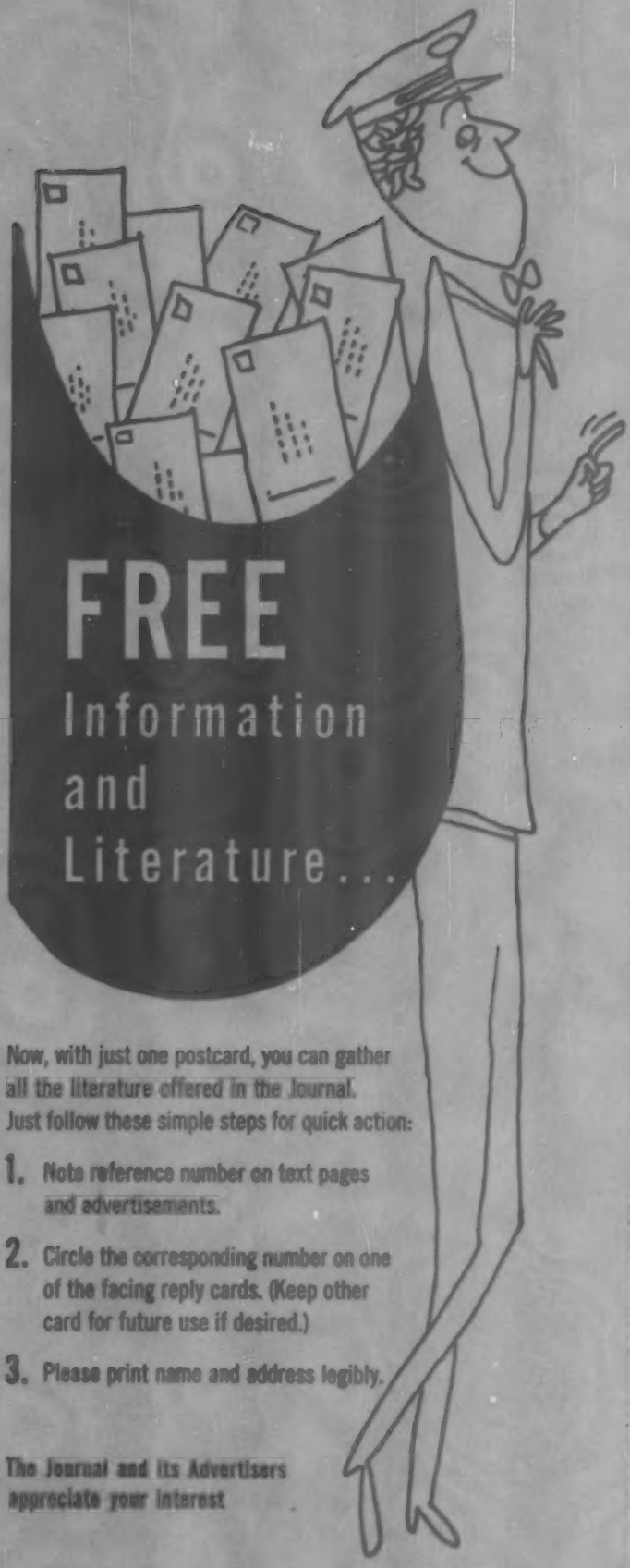
The world's leading manufacturer of arc welders and electrodes, ac motors and battery chargers.

For details, circle No. 38 on Reader Information Card

READER INFORMATION CARD



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8	33	58	83	108	133
9	34	59	84	109	134
10	35	60	85	110	135
11	36	61	86	111	136
12	37	62	87	112	137
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Metallurgy of Bonding in Brazed Joints

Part III—The Role of Intermetallic Compounds in Brazed Joints

The occurrence and effects of intermetallic compound formation in brazed joints is investigated, utilizing low-carbon steel as base metal and Ag-Si, Ag-Zn and Ag-Sn alloys as filler metals

BY NIKOLAJS BREDZS AND HARRY SCHWARTZBART

ABSTRACT. This paper is part of a series devoted to a study of the metallurgy of bonding in brazed joints, and describes a study of the role of intermetallic compounds in brazed joints.

It is apparent that every element apt to form a given intermetallic compound with the base metal will do so only if the concentration of this element in the molten filler metal is high enough. Below this "critical concentration limit" the given element at a given temperature cannot form a given intermetallic compound. Furthermore, the effects on the mechanical properties of brazed joints containing intermetallic compounds depend on the amount, geometry and distribution of the compounds. In the present program, steel was brazed with Ag-Si, Ag-Zn, Ag-Sn, and Cu-Fe-B alloys. It was attempted to establish the "critical concentration limit" for the various systems investigated and its dependence on such factors as the free energy of formation of the intermetallic compound, the heat of reaction of this formation, and the partial molar free energies of solution of the element (forming the intermetallic compound) in the liquid filler metal. The effects of compound formation on mechanical properties were also studied.

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Paper presented at the AWS National Fall Meeting held in Detroit, Mich., Sept. 28–Oct. 1, 1959.

Introduction

The first and the second paper[1, 2] in the series on "Metallurgy of Bonding in Brazed Joints" dealt with the interactions between the molten filler metal and the solid base metal taking place at the base metal-filler metal interface and in the base-metal grain boundaries penetrated by the liquid filler metal. In order to exclude all complicating factors, it was necessary to select for those studies such base metal-filler metal combinations which do not form intermetallic compounds.

The present paper, which is the third one in the series, deals with the problem of the role of intermetallic compounds in brazed joints. Accordingly, in this case it was necessary to select base metal-filler metal combinations which can form intermetallic compounds. In the course of the experimental work it was gradually recognized that the constituents of the filler metal which can form intermetallic compounds with the base metal do not all behave in the same manner. Some of the elements are more active and might form intermetallic compounds with the base metal as soon as the filler metal is molten and begins to enter the capillary gap, whereas the others do not form intermetallic compounds at all or form them only under specific temperature and concentration conditions. Therefore, the approach to this study was to determine the "critical concentration limit" of an element in a filler alloy, above which compounds would form with base metal under brazing conditions, and below which they would not.

To understand better the role of intermetallic compounds in brazed joints, the fundamental factors determining the "critical concentration limit" were studied. This required the consideration of the pertinent phase diagrams, where available, the free energies of the formation of the intermetallic compounds, the partial molar free energies of solution of a given element in the molten filler metal at a certain temperature and concentration, diffusion rates in the intermetallic compound layers and certain other factors. On the basis of the experimental data, it has been attempted to explain the rather complex mechanism of the formation of intermetallic compound (or intermediate phase) layers on the base metal-filler metal interface and its correlation to the mechanical properties of a brazed joint.

For present purposes, the definition of an intermetallic compound will be taken as that given in the ASM *Metals Handbook*,[3] namely:

Table 1—Heats of Formation of Hume-Rothery Phases[a]
($-\Delta H_{298}$ in kcal per g-atom)

β-Brass type (V.E.C.—3:2)		γ-Brass type (V.E.C.—21:13)		ε-Brass type (V.E.C.—7:4)	
Composition	$-\Delta H_{298}$	Composition	$-\Delta H_{298}$	Composition	$-\Delta H_{298}$
Cu Zn	2.5	Cu_5Zn_8	2.9	$Cu Zn_3$	2.0
Cu_5Sn	...	$Cu_{31}Sn_8$	1.4	Cu_3Sn	1.8
Ag Zn	1.7	Ag_5Zn_8	1.9	$Ag Zn_3$	1.3
Ag Cd	1.3	Ag_5Cd_8	1.4	$Ag Cd_3$	1.2

[a] According to Kubaschewski and Evans.[17]

"Intermetallic compound is a compound of two or more metals that has a characteristic crystal structure and may have a definite composition or a range of compositions corresponding to a solid solution."

The most recent developments in physical metallurgy may have rendered this definition somewhat oversimplified and obsolete. However, it is beyond the scope of this work to consider the various types of possible compounds. The important consideration to a brazing metallurgist is that intermetallic compounds of fixed or variable composition are generally brittle, and it was of primary concern in this program to determine the effects of compound formation on the properties of brazed joints.

The occurrence and effects of intermetallic compound formation in brazed joints have not been heretofore examined as completely as in the case of soldered joints, and particularly not so with a fundamental approach. The fairly early and extensive literature[4-12] concerned with intermetallic compounds in soldering has shown the time and temperature dependence of the thickness of the compound layer formed between filler metal and base metal, the effect of intermetallic compounds on the tensile and creep strength of soldered joints and on the location of fracture, and the effects of small amounts of impurity elements in the filler metal on compound formation. In regard to the literature[13-15] on intermetallic compounds in brazed joints, very few experimental data are presented, and the discussions have been principally theoretical. The view is widely held that filler-metal constituents that might form intermetallic compounds with a particular base metal are to be avoided in brazing alloy formulation. This is gross oversimplification, since it is not possible at present to predict the formation of compounds, or, if compounds do form, that their quantity and distribution will result in reduced joint strength. Many of the commercial brazing alloys used satisfactorily today contain elements which might have been expected to form compounds with particular base metals, resulting in reduced joint strength. Such is not the case, and these alloys might not have been developed if their formulators had prejudged the situation in regard to the occurrence and effects of compound formation.

Accordingly, the research program was planned to yield information on the following: to determine the conditions (especially concentration of the element forming intermetallic compounds with the base metal) under which intermetallic compounds form in certain selected filler metal-base metal systems, and to determine the distribution of such compounds and their effect on joint strength.

Selection of the Systems for Study

Plain-carbon steel was selected as base metal and silver-silicon alloys, silver-zinc alloys and silver-tin alloys as filler metals for this study. The advantages of using these materials for this study are that (1) silver and iron are virtually insoluble in each other and thus do not offer undesired metallurgical complications; (2) silicon, zinc and tin all form intermetallic compounds with iron; and (3) silicon, zinc and tin have widely varying affinities for iron. Some inference of the relative affinities can be derived from the following analysis.

Hume-Rothery[16] points out that when an electropositive constituent (in our case, Fe) forms a series of intermetallic compounds with various elements of electronegative nature (Si, Sn and Zn, in our case), then the most electronegative element (Si), as a rule, forms more stable intermetallic compounds (heat of formation of $FeSi_{(s)}$: $-\Delta H_{298} = 19.2 \pm 1.5$ kcal/mole) with the highest melting points (mp of FeSi = 1410° C), and the least electronegative element (Zn), as a rule, forms more unstable intermetallic compounds, with the lowest melting points. (The Γ-phase has the highest melting point, 782° C, of all the Fe-Zn intermediate phases). Accordingly, it can be postulated, at least qualitatively, that Zn must have a much lower affinity for iron than does Si.

Furthermore, considering the more or less electronegative character of Ag, the more electropositive Zn must have a much higher affinity for Ag than does the electronegative Si. The system Ag–Si has no intermetallic compounds; consequently, there cannot be any data on the heats of formation of Ag-Si intermetallic compounds. However, the heats of formation of Ag-Zn intermetallic compounds have been determined by Kubaschewski and Evans.[17] They point out that "those who are concerned especially with alloy phases should note that in systems of the Hume-Rothery type the highest heat of formation is

Table 2—Thermochemical Data of Binary Metallic Systems with Extensive Homogeneity Ranges[a]

System	Thermochemical function	Temp., °C	N_2[b] 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
(Ag-Sn)	$\Delta\bar{H}(Sn)$[d]	627	...	−3540	−2630	−1875	−1240	−750	−395	−165	−35
(Ag-Zn)	$\Delta\bar{G}(Zn)$[c]	700	...	...	−5200	−3740	−2500	−1350	−770	−490	−200
(Fe-Si)	ΔH[e]	1600	−2780	−5330	−7420	−8610	−9010	−8340	−6750	−4900	−2460

[a] According to Kubaschewski and Evans.[17]
[b] N_2 = atomic fraction of the second element named in the first column.
[c] $\Delta\bar{G}$ = partial molar free energy of solution.
[d] $\Delta\bar{H}$ = partial molar heat of solution.
[e] ΔH = integral heat of mixing.

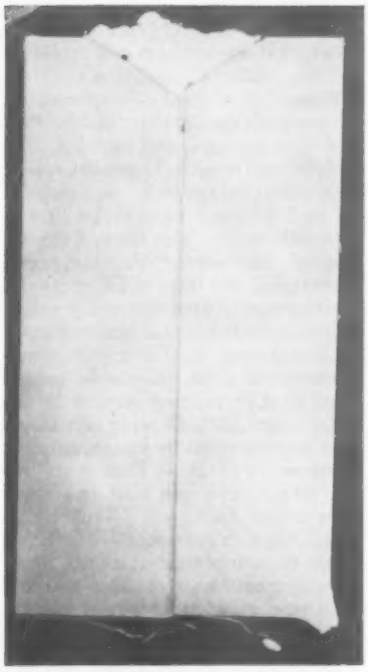

Fig. 1—Low-carbon steel joint brazed with the 99% Ag – 1% Si alloy. Unetched. ×5.

The filling groove in the upper part of the joint is filled with the solidified filler metal

generally found in phases of the γ-brass type with a valency electron/atom ratio (V.E.C.) of 21/13." The extent to which this generality holds may be seen from Table 1, which is taken from their work.

From the data presented in Table 1 it is apparent that Cu has a much higher affinity for Zn than for Sn. This is in the best agreement with the Hume-Rothery theory: namely, the electronegative Cu must have a higher affinity for the more electropositive Zn than for the less electropositive Sn. Accordingly, it can also be postulated that the electronegative Ag must have a higher affinity for the more electropositive Zn than for the less electropositive Sn. This postulation is also confirmed, though indirectly, by comparing the partial molar heats of solution of molten Sn in molten Ag with the partial molar free energies of solution of molten Zn in molten Ag (assuming negligible volume change on combining). In all proportions, the free energy values for Zn are considerably larger than the corresponding heat of solution values for Sn. The pertinent data are summarized in Table 2, which also includes the corresponding data for the partial molar heats of solution of molten Si in molten Fe.

From these thermochemical data it is apparent that, of the three elements considered (Si, Zn, Sn), Si has the highest affinity for Fe and the lowest for Ag. On the other hand, Zn has the lowest affinity for iron and the greatest affinity for Ag. Consequently, it can be postulated that Si must have a small critical concentration limit in the system steel-(Ag–Si) alloys and that Zn must have a quite high critical concentration limit in the system steel-(Ag–Zn) alloys. Unfortunately, no data are available for a more or less accurate estimation of the affinity of Sn for Fe. Taking into consideration the striking similarity of the Fe-Sn and Fe-Zn binary phase diagrams, it might be assumed that the affinities of Fe for Sn and of Fe for Zn are approximately equal. However, since Ag has a much larger affinity for Zn than for Sn, it can be postulated that the critical concentration limit of Sn in the system steel-(Ag–Sn) alloys must be somewhere between the two extreme values of the critical concentration limits of Si and of Zn.

Experimental Results

The experimental results are presented in the following sections. Three-in. long, $^3/_4$-in. diameter low-carbon steel bars were induction brazed according to procedures already described in detail.[1] Stainless-steel wires of various diameters were used as spacer wires. After brazing, the bars were turned to 0.505-in. tensile specimens. Joint thickness was measured with a microscope, and the specimens were tension tested.

Silver-silicon Filler Metal

Figures 1 to 8 show a series of photomicrographs made on the polished cross section of a low-carbon steel joint about 0.01 in. thick, brazed with the 99% Ag – 1% Si alloy. Figure 1 shows the entire cross section of the joint. For the sake of better surveillance of these photomicrographs, Figure 2 represents a schematic sketch of the entire section of the joint shown in Fig. 1. The squares indicate the numbers of the pertinent photomicrographs.

It can be seen from the photomicrographs that a thick layer of

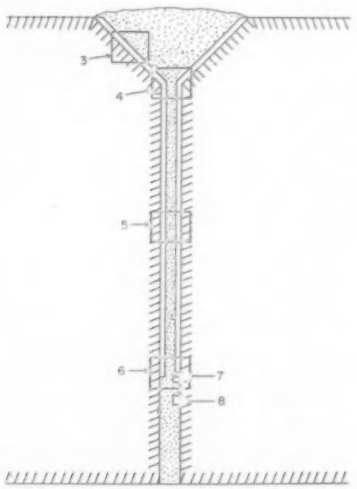

Fig. 2—Schematic diagram of the brazed joint shown in Fig. 1. The squares and numbers indicate the sections of the joint shown in Figs. 3, 4, 5, 6, 7 and 8

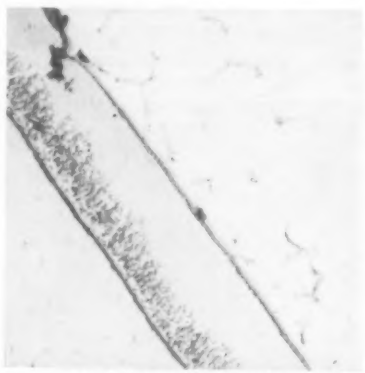

Fig. 3—Steel-filler metal interface at the left edge of the filler-metal groove shown in the upper section of Fig. 1. Unetched. × 150. (Reduced by 30% upon reproduction)

In the right upper section of the photomicrograph is the filler metal which consists of large grains of pure silver surrounded by a net of an Ag-Fe-Si ternary eutectic. A thick layer of iron-rich intermediate phases, which crosses the photomicrograph diagonally, separates the filler metal from the steel

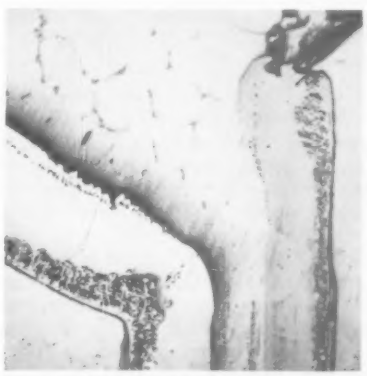

Fig. 4—Bottom section of the filling groove and the upper section of the brazed joint shown in Fig. 1. Unetched. × 150. (Reduced by 30% upon reproduction)

The two thick layers of the iron-rich intermediate phase are clearly visible on both sides of the filler-metal layer. The fine net of the ternary eutectic surrounding the silver grains indicates that at the time of solidification the filler metal still had appreciable amounts of silicon and iron in solution. However, in the lower section of the photomicrograph this net gradually starts to disappear

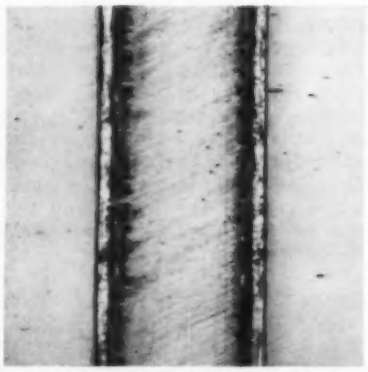

Fig. 5—Section of the brazed joint shown in Fig. 1. Unetched. × 150. (Reduced by 30% upon reproduction)

This section is slightly below the middle part of the joint. The two iron-rich intermediate phase layers on both sides of the filler-metal layer are quite thin. No signs of the ternary eutectic are visible in the filler-metal layer

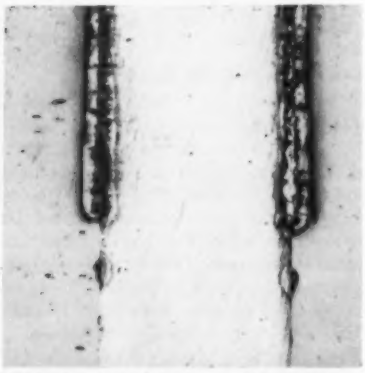

Fig. 6—Section of the brazed joint shown in Fig. 1. Unetched. × 150. (Reduced by 20% upon reproduction)

This section was located in the lower part of the joint. The two iron-rich intermediate-phase layers terminate in this section. Below this section the steel-filler metal interface is completely free of intermediate phases

intermediate phase or phases is visible between the filler metal layer and the base material. From Fig. 2 and the appropriate photomicrographs, it is seen that this phase extends about three-quarters of the way through the capillary; and from Figs. 6 and 7, that it has replaced the steel base metal to a considerable depth. From the silver-silicon binary diagram, Fig. 9, (the iron-silicon binary diagram is given in Fig. 10), it is seen that the liquidus of the 99% Ag – 1% Si alloy is at about 935° C. Since this joint was brazed by induction heating to just above the liquidus of the filler metal, it is difficult to rationalize the extensive attack of the steel base metal and the thickness of the intermediate zone on the basis of the application of external heat alone. The answer may be found in the heat generated at the filler metal-base metal interface when Fe and Si combine to form the intermetallic compound FeSi, which heat melts additional base metal, forming an iron-rich second liquid.

Support for this explanation can be found in the work of Walter,[18] discussed and amended in later years by Kubaschewski and Evans.[17] Walter mixed 80 weight percent of iron powder with 20 weight percent of silicon powder (which corresponds to the eutectic composition, see Fig. 10, point e_1) in a clay crucible, and slowly heated the mixture. At 1250° C the mixture started to react quite violently, and the temperature of the mixture climbed rapidly to 1810° C. At this temperature the mixture was completely molten. Walter calculated the heat of formation of the Fe-Si intermetallic compounds in the 80.0% Fe – 20.0% Si mixture, and found it close to 8050 cal/mole. The most recent determination made by Kubaschewski and Evans,[17] yielded a value of 8200 cal/mole. The heat of formation of the pure FeSi compound, determined for the solid state by Weibke and Kubaschewski,[19] yields $-\Delta H_{298} = 19.2 \pm 1.5$ kcal/mole.

Fig. 7—Tip of the intermetallic compound layer at the steel-filler metal interface shown in the right, lower section of Fig. 6. Unetched. × 1000. (Reduced by 30% upon reproduction)

This photomicrograph shows the depth to which the base metal was melted during brazing. By comparing the original steel-filler metal interface (clearly visible in the lower section of the photomicrograph) with the melt-solid interface at brazing temperature (this interface is clearly outlined by the curved line separating the base metal from the intermediate-phase layer in the right, upper section of the photomicrograph), one might estimate the thickness of the dissolved steel layer

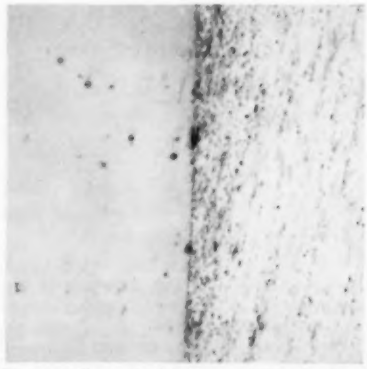

Fig. 8—The steel-filler metal interface just below the tip of the intermediate-phase layer shown in Fig. 7. Unetched. × 1000. (Reduced by 30% upon reproduction)

No signs of iron-rich intermediate phases are visible on the steel-filler metal interface

Considering the available thermochemical data, it can be postulated that in brazing steel with the 99.0% Ag – 1.0% Si alloy additional heat was supplied by the exothermic reaction, Fe + Si = FeSi + 19,200 cal, which took place at the steel-filler metal interface. This hypothesis appears even more convincing if one considers that at about 1000° C one gram-atom of iron reacting with one gram-atom of silicon develops so much heat (about 19,200 cal/mole) that it can melt the resulting gram-molecule weight of FeSi plus four additional gram-atoms of iron (heat of fusion of iron = 3600 cal/g-atom), provided that no heat losses occur.

In the right upper section of Fig. 3 the characteristic structure of the solidified filler metal appears; it consists of large grains of silver surrounded by a fine net of the ternary Ag-Fe-Si eutectic, which contains 99% Ag – 0.5% Fe-0.5% Si and melts at 840° C.[20] The fine net of the ternary eutectic presumably was the last portion of the filler metal still in the liquid state at 840° C. The considerable thickness of the intermediate phase layer at the steel-filler metal interface indicates that considerable amounts of silicon were extracted from the molten 99.0% Ag – 1.0% Si alloy. On the other hand, the fine net of the ternary eutectic in the solidified filler metal indicates that not all of the silicon was extracted and that some small amounts of silicon were still present in the filler metal at the time of solidification.

In Fig. 4, which shows the bottom section of the filler-metal groove with the upper section of the capillary gap, the fine net of the ternary eutectic is still visible in the filler-metal matrix in the upper part of the photomicrograph. However, it disappears gradually in the lower section of the filler-metal groove.

In Fig. 5, which shows the center section of the joint, no signs of the ternary eutectic can be discerned in the filler metal. In this section of the joint, the iron-rich, intermediate

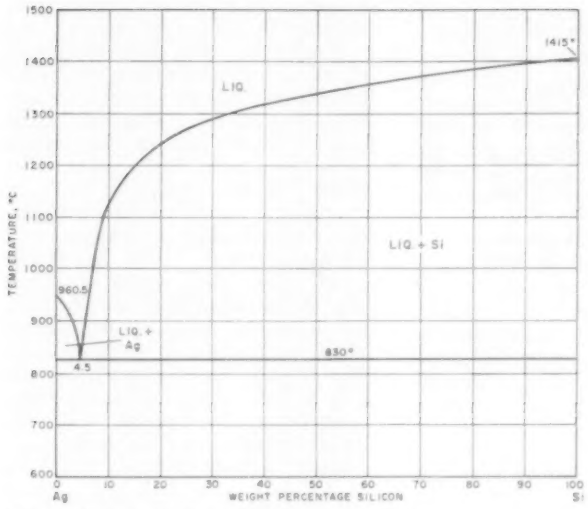

Fig. 9—Diagram of the silver-silicon system[26]

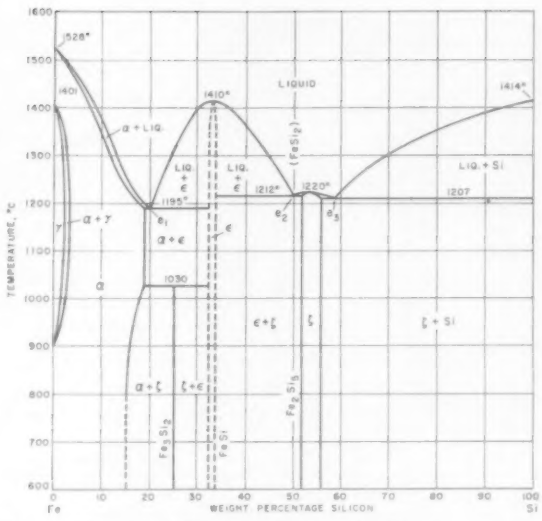

Fig. 10—Diagram of the iron-silicon system[30]

phase layers on both sides of the filler-metal layer are already much thinner, and they disappear completely in the lower part of the joint shown in Figs. 6, 7 and 8.

In order to gain further evidence that the wide, intermediate iron-rich zone between the base metal and the silver-rich filler metal in Figs. 1 through 7 was a second liquid at the brazing temperature, the following experiment was performed.

An alundum crucible with about 20 grams of the 99% Ag – 1% Si alloy and a 2-g low-carbon steel (Armco iron) plate on top of the alloy was inserted in an induction coil and heated under a bell jar in 10% H_2 + 90% N_2 atmosphere. By turning the high-frequency current on and off, heating was maintained at a low rate. As soon as the 99% Ag – 1% Si alloy started to melt, the power input was further decreased so that the alloy would not heat over its liquidus temperature (935° C). During the next five minutes the alloy was melting slowly until, at the end of this period, all the silver-silicon alloy was molten and only the undissolved, solid-steel plate floated on the surface of the molten alloy. At this time the power was turned off, and the melt was allowed to cool in the 10% H_2 + 90% N_2 atmosphere.

During the melting period it was observed that a gray, liquid layer of a separate alloy phase, which apparently was immiscible with the molten Ag-Si alloy, formed gradually around the floating steel plate. At the end of the melting period, when an appreciable part of the steel plate had melted, the gray-colored, liquid iron-rich phase layer almost completely covered the liquid silver-silicon alloy. After cooling to room temperature, the solidified melt was cross sectioned and metallographically examined.

Figure 11 shows the cross section of the unmelted steel plate in the right, upper corner of the photomicrograph; the adjacent gray layer of the solidified iron-rich phase is in the left, upper corner of the photomicrograph; and below it is the white layer of the solidified silver-rich phase of the Ag-Si-Fe alloy. The silver-rich phase consists of small, white grains of almost pure silver surrounded in the grain boundaries by a fine net of the ternary Ag-Si-Fe eutectic (mp 840° C, see point E_3, Fig. 12), which is most clearly visible in the right section of the photomicrograph. (It should be noted that whereas the fine net in the silver-rich portion has been referred to as the lowest melting ternary Ag-Si-Fe eutectic, mp 840° C, this is not quite true, as is shown on Fig. 12. The binary Ag-Si eutectic melts at 830° C, point e_4, so that, to be exact, the fine net in the silver-rich portion of Fig. 11 consists of iron plus Ag-Si binary eutectic.)

Another interesting observation from Fig. 11 is the crack which separates the iron-rich zone from the base steel plate.

The results of this experiment, make possible the following explanation of the events which occurred. Upon heating an alloy of 99% Ag – 1% Si in contact with steel, as the Ag-Si alloy slowly melted, the silicon combined with the iron forming an Fe-Si compound at the liquid-solid interface. The high heat of formation of this compound released sufficient heat to melt additional base metal at the interface. By drawing a tie-line on Fig. 12 from the iron corner to the 99% Ag – 1% Si point, we see that this should result in two immiscible liquids, one iron-rich and the other silver-rich. Although the external heat applied raised the temperature to no higher than 950° C, the local temperature at the liquid-solid interface reached at least 1140° C because of the heat liberated when the Fe-Si compound formed. The temperature of 1140° C is cited because this is the lowest melting liquid in the iron-rich corner

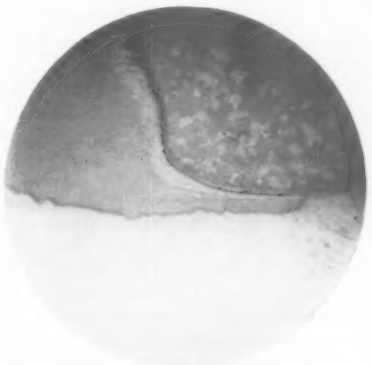

Fig. 11—Cross section through a low-carbon steel plate (located in the right, upper corner of the micrograph), surrounded by a gray-colored layer of the solidified, iron-rich phase of the Fe-Si-Ag alloy, and the white-colored layer of the solidified, silver-rich phase of the solidified Ag-Si-Fe alloy. Etchant: 2% Nital. × 25. (Reduced by 40% upon reproduction)

An uninterrupted crack separates the steel plate from the solidified Fe-Si-Ag alloy

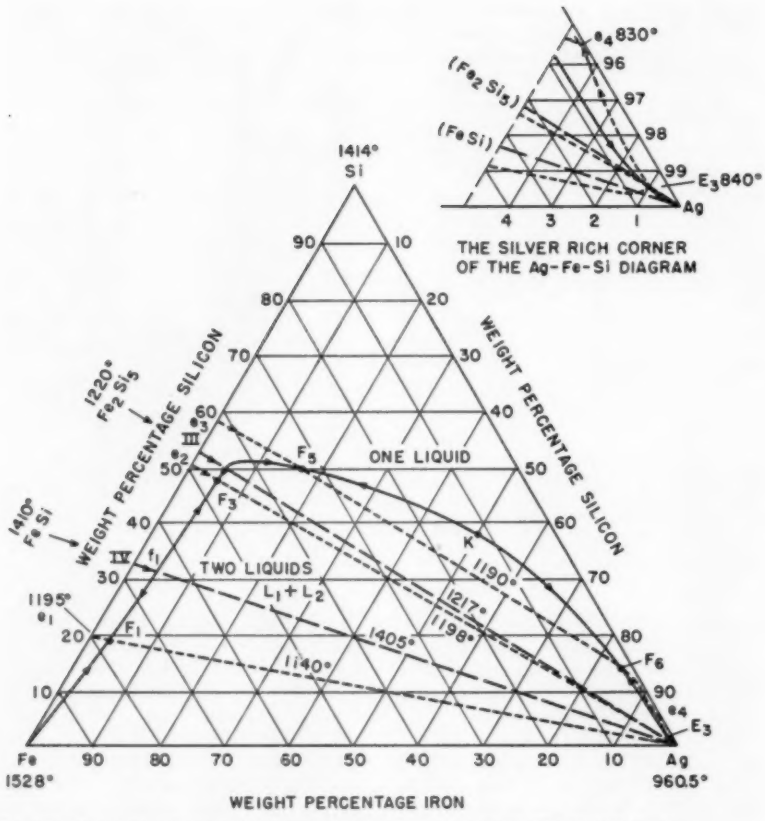

Fig. 12—Ternary phase diagram: Ag-Fe-Si.[20] Line Fe-F_1-f_1-F_3-F_5-K-F_6-E_3-Ag outlines the region of liquid immixibility

Actually, the local temperature at the liquid-solid interface may have been higher than 1140°C depending upon the diffusion rate of silicon in iron relative to the heating rate. If the base metal at the interface were pure iron, not alloyed by diffusion of silicon from the filler metal, then a temperature of 1528° C must have been attained locally. at the interface. Actually, the temperature attained was probably between 1140 and 1528° C, some diffusion of silicon into the base metal having occurred during heating. It is apparent from the crack visible on Fig. 11 that the iron-rich material immediately adjacent to the base metal was sufficiently high in silicon to reduce its ductility to essentially zero.

The results of the tensile tests of the low-carbon steel bars brazed with the 99.0% Ag – 1.0% Si alloy, which are summarized in Table 3, supplement the results of the metallographic investigation effectively. Some of the joints which fractured at the plane of symmetry of the filler-metal disk and did not show any signs of intermediate phase layers in the fractured filler metal yielded the same high-tensile strength as low-carbon steel joints brazed with pure silver in the corresponding joint thickness range (samples Si-2, Si-10 and Si-11). Apparently, in these joints the silicon was extracted from the molten filler metal already in the filling groove, so that the filler-metal disk in the joint consisted of almost pure silver. Therefore, these joints yielded quite high tensile strength, corresponding to the tensile strength of pure silver joints.

On the other hand, all the joints which broke in tension unsymmetrically and showed the gray, shiny, intermediate phase layers in the fractured filler metal yielded much lower tensile strength (samples Si-5, Si-6 and Si-8).

Due to the extremely high affinity of iron for silicon, the critical concentration limit of silicon (the element forming the intermetallic compounds) in silver-silicon filler metals must be almost zero, or at least much less than 1.0%.

However, some recent investigations performed by Y. H. Chou[21] and also by Schadel, Derge and Birchenall[22] show that liquid iron does not extract *all* the silicon from liquid silver; consequently, there must be a certain proportion of silicon concentration between the two liquid phases, which, roughly, could be in the order of magnitude of 1000:1 (1000 in iron-rich phase, 1 in silver-rich phase). The fact that liquid iron does not extract all the silicon from liquid Ag-Si alloy is borne out by the Fe-Si-Ag diagram.[20]

Accordingly, it can be concluded that even in the base metal-filler metal combination, steel-(Ag-Si) alloy, the critical concentration limit of silicon in molten silver is not zero, though nearly so.

Copper-boron Filler Metal

It has been postulated that the element boron, which presumably has an even higher affinity for iron than has silicon, might behave in the brazing of steel in quite similar manner as silicon; i.e., the critical concentration limit of boron in the filler metal might be quite close to zero or, at least, much closer to zero than in Ag-Si alloys. In order to prove this postulation it would be necessary to braze steel with Ag-B alloys. Unfortunately, boron is virtually insoluble in liquid or solid silver, and therefore it was necessary to select another filler metal for study. Since boron is soluble in copper, and copper dissolves comparatively little iron in the liquid state, Cu-B alloys were utilized for some preliminary studies. However, it was recognized that in this system the critical

Table 3—Tensile-test Results of Low-carbon (1020) Steel Bars Brazed with 99% Ag – 1% Si Alloy

Sample No.	Joint thickness, in.	Ultimate tensile strength, psi	Remarks
Si-2	0.00761	53,100	Almost voidless, broke in filler metal
Si-5	0.00772	35,800	Fractured partly through the layer of the iron-rich phase
Si-6	0.00034	37,900	A large portion of fracture through the iron-rich phase
Si-8	0.00050	54,200	Same as above
Si-10	0.00013	70,400	Almost voidless. Very small fringe of fracture through iron-rich phase
Si-11	0.00004	67,000	Same as above

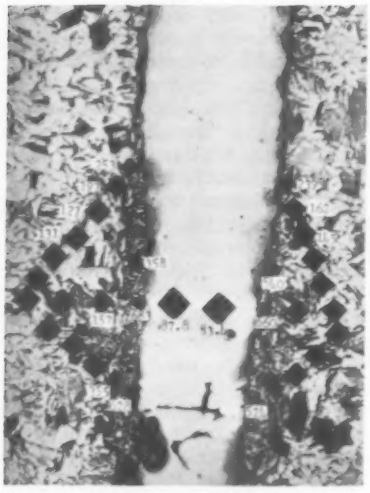

Fig. 13—Low-carbon (1020) steel joint brazed with Cu-Fe-B alloy (98.5% Cu – 1.09% B – 0.41% Fe). Etchant: 2% Nital. × 150. (Reduced by 50% upon reproduction)

The readings indicate the location of the quite hard (VHN–660 and 683) and brittle layer of a boron-rich phase on the steel-filler metal interface on both sides of the joint

concentration limit of boron cannot be zero, or even close to zero, since copper has considerable affinity for boron and even forms intermetallic compounds with boron as shown by Lihl and Feischl.[23] Some preliminary work performed at the Armour Research Foundation has proved that liquid copper can even extract considerable amounts of boron from liquid Fe-B melts.

It was shown experimentally that in brazing plain-carbon, as well as alloy steels, with Cu-B alloys, intermetallic compounds form at the steel-filler metal interface (Figs. 13 and 14). The formation of a liquid, iron-rich phase in these joints is possible since the melting point of the lowest melting eutectic (96.2% Fe – 3.8% B) in the Fe-B system is equal to 1149° C, which is only about 65° C higher than the melting point of pure copper, 1083° C. Thus, the total amount of boron is distributed between two possible liquid phases. Comparing the distribution of boron between the iron-rich and the copper-rich phases to the distribution of silicon between iron-rich and silver-rich phases when brazing steel with silver-silicon alloy, it is apparent that there is a considerable difference in the distribution of these elements between the two phases. The proportion of silicon concentration in the two phases was, roughly, 1000:1 (1000 in iron-rich phase, 1 in the silver-rich phase). The proportion of boron concentrations in these two liquid phases was, roughly, 15:1 (15 in iron-rich phase, 1 in copper-rich phase).[24] Accordingly, it can be postulated that iron has a much greater tendency to extract silicon from liquid Ag-Si alloys than boron from liquid Cu-B alloys, presumably due to the fact that copper has a much higher affinity for boron than silicon has for silver.

Due to the precipitation of the excess of the dissolved iron from the supersaturated filler metal during the cooling period, some of the steel joints brazed with Cu-Fe-B alloys yielded a layer of precipitated iron dendrites on top of the solidified iron-rich phase layer. Accordingly, these joints had two separate layers on each of the steel-filler metal interfaces.

In tension testing steel joints brazed with Cu-Fe-B alloys with a boron content not exceeding 0.25% B, all broke along the plane of symmetry of the filler-metal disk; and some of them broke in the base metal. These joints yielded relatively high tensile strength. On the other hand, the steel joints brazed with the 98.5% Cu–1.09% B–0.41% Fe alloy quite frequently broke through the brittle, iron-rich phase layer at the base metal-filler metal interface and generally exhibited lower tensile strength (except the extremely thin joints).

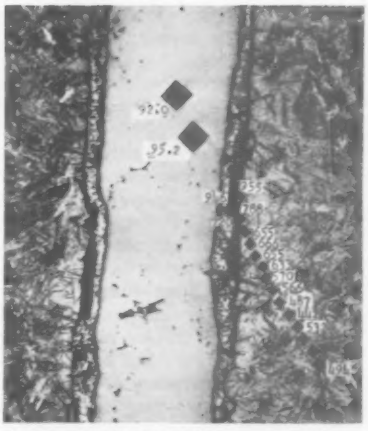

Fig. 14—A 4340 steel joint brazed with Cu-Fe-B alloy (98.5% Cu – 1.09% B – 0.41% Fe). Etchant: 2% Nital. × 150. (Reduced by 50% upon reproduction)

The hardness readings indicate the location of the extremely hard (VHN—945 and 955) and brittle layers of boron-rich phases on the steel-filler metal interface, on both sides of the joint

Silver-zinc Filler Metal

Table 4 presents the tensile properties of a series of low-carbon steel bars brazed with silver-zinc filler metal ranging in zinc content from 5% to 50%. It can be seen that joint strength was independent of zinc content from 5 to 25% zinc, and that fracture always occurred at the plane of symmetry of the filler-metal disk. Metallographic examination did not reveal the presence of any intermetallic compounds at the base metal-filler metal interface.

The results obtained with the 50% Ag – 50% Zn filler metal were quite different. Most of the bars broke in the lathe during machining of the brazed cylinders into tensile specimens. Only with extreme precautions was it finally possible to prepare three tensile bars. All

Table 4—Tensile-test Results of Low-carbon (1020) Steel Bars Brazed with Silver-zinc Alloys

Specimen No.	Filler metal	Joint thickness, in.	Ultimate tensile strength, psi	Location of fracture	Remarks
ALC-387	95%Ag – 5%Zn	0.00014	37,600	Plane of symmetry	Sound and voidless
ALC-388	95%Ag – 5%Zn	0.00230	44,500	Plane of symmetry	Sound and voidless
ALC-389	55%Ag – 5%Zn	0.00500	35,300	Plane of symmetry	Some small voids (5%)
ALC-384	90%Ag – 10%Zn	0.00043	42,600	Plane of symmetry	Some small voids
ALC-385	90%Ag – 10%Zn	0.0060	37,700	Plane of symmetry	Some small voids
ALC-394	75%Ag – 25%Zn	0.00038	36,700	Plane of symmetry	Some small voids (5%)
ALC-395	75%Ag – 25%Zn	0.0046	38,300	Plane of symmetry	Almost voidless (2%)
ALC-396	75%Ag – 25%Zn	0.0046	39,800	Plane of symmetry	Sound and voidless
LC-AZ-50-1	50%Ag – 50%Zn	Not measurable	5,000	Base-filler interface	....
LC-AZ-50-3	50%Ag – 50%Zn	0.00504	11,500	Base-filler interface	....
LC-AZ-50-4	50%Ag – 50%Zn	0.00601	5,925	Base-filler interface	....

three bars broke in tension at the base metal-filler metal interface.

Metallographic investigation of the polished cross sections of these joints did not reveal the presence of any intermediate phase layers at the steel-filler metal interface, not even under the highest magnification (see Fig. 15). The photomicrographs of these joints demonstrated the extreme brittleness of the 50% Ag – 50% Zn alloy. The solidified filler metal in the joint, before tension testing, had numerous large cracks in the filler metal as well as on the base metal-filler metal interface. Since at room temperature zinc has about a four times larger coefficient of thermal expansion (39.7 micro.-in./° C) than iron (11.7 micro.-in./° C), and about a two times larger coefficient of thermal expansion than silver (19.7 micro.-in./° C), it might be postulated that the 50% Ag–50% Zn alloy has about a three times larger coefficient of thermal expansion than steel. Therefore, by cooling the steel joints brazed with the 50% Ag – 50% Zn alloy to room temperature, considerable shear stress might arise at the base metal-filler metal interface. The extreme brittleness of the filler metal combined with the large difference in thermal expansion of the two metals might explain the cracking of the solidified filler metal, and also the fracture of the joint at the base metal-filler metal interface. In fact, Weigert[25] has shown the extreme brittleness of Ag-Zn alloys containing more than 30% Zn.

The strength of the joints made with the 50% Ag – 50% Zn alloy was much lower than that of joints made with the alloys containing 25% Zn or less, as shown in Table 4.

× 150

× 1000

Fig. 15—Cross section through the upper part of a low-carbon (1020) steel joint brazed with the 50% Ag – 50% Zn filler metal. Unetched. (Reduced by 1/3 upon reproduction)

Silver-tin Filler Metal

The Ag-Sn binary phase diagram shows three single-phase composition regions:

1. α-phase, extending from 0.0 to 10.0 weight percent Sn.
2. ζ-phase, extending from 12.8 to 19.5 weight percent Sn.
3. ϵ-phase, extending from 23.7 to 26.8 weight percent Sn.

Since more conclusive experimental results can be obtained with homogeneous alloys, the following one-phase filler metals were investigated.

1. a 90.0% Ag – 10% Sn alloy (α-phase) with a melting range from about 800–900° C.
2. a 85.5% Ag – 14.5% Sn alloy (ζ-phase), mr 724–830° C.
3. a 74.0% Ag – 26.0% Sn alloy (ϵ-phase), mr 480–670° C.

Metallographic examination of low-carbon (1020) steel bars brazed with the 90.0% Ag – 10.% Sn alloy as well as with the 85.5% Ag – 14.5% Sn alloy did not show any signs of Fe-Sn intermediate phases at the steel-filler metal interfaces.

The joint brazed with the 74.0% Ag – 26.0% Sn alloy was brittle and broke in the process of cross sectioning. The half of the joint which retained the largest part of the filler metal layer was mounted and metallographically examined. This revealed a continuous crack along the base metal-filler metal interface, indicating that a layer of brittle Fe-Sn intermediate phases might have formed at the interface.

The tensile properties of low-carbon steel bars brazed with Ag-Sn alloys are tabulated in Table 5 and plotted as functions of joint thickness in Fig. 16, along with the curve for joints brazed with pure silver, for comparison purposes. From Fig. 16, it is seen that joint strength is relatively independent of joint thickness for the Ag-Sn filler alloys. The behavior of joints brazed with 74% Ag – 26% Sn filler metal was interesting, as shown in Fig. 17. The fracture took place exclusively at the steel-filler metal interface, possibly through an extremely thin layer of Fe-Sn intermediate phases.

Also seen in Fig. 16 is the decrease in joint strength with increasing tin content. This decrease in strength cannot be explained on the basis of the data at hand, and may or may not be associated exclusively with the formation of intermediate phase layers at the base metal-filler metal interface. No intermediate phases were metallographically visible at the base metal-filler metal interface in the 10% Sn or the 14.5% Sn filler metals; yet the strength of the latter was lower, and fracture did occur at the interface. This could be a reflection of the development of different bond strength between low-carbon steel and α-(Ag-Sn), and between low-carbon steel and ζ-(Ag-Sn), irrespective of the de-

Table 5—Tensile-test Results of Low-carbon (1020) Steel Bars Brazed with Silver-tin Alloys

Sample No.	Filler metal	Joint thickness, in.	Ultimate tensile strength, psi	Remarks
ALC-328	90%Ag – 10%Sn	0.00036	61,400	Broke in base metal
ALC-383	90%Ag – 10%Sn	0.00620	59,000	Sound and voidless, broke at plane of symmetry
LC-15SN-AG1	85.5%Ag – 14.5%Sn	Not measurable	31,400	Interface fracture
LC-15SN-AG2	85.5%Ag – 14.5%Sn	0.00365	35,100	Interface fracture
LC-15SN-AG3	85.5%Ag – 15.5%Sn	0.00483	30,900	Interface fracture
LC-26Sn-AG1	74%Ag – 26%Sn	Not measurable	16,600	Interface fracture
LC-26SN-AG2	74%Ag – 26%Sn	0.00373	16,150	Interface fracture
LC-26SN-AG3	74%Ag – 26%Sn	0.00500	15,850	Interface fracture

velopment of intermediate phases at the interface. Of course, the possibility exists that intermediate phases were present and were not metallographically observable. The strength of joints brazed with 74% Ag – 26% Sn, the ϵ-(Ag-Sn) phase, was considerably reduced; and in this case, the peculiar fracture illustrated in Fig. 17 was obtained.

Discussion of Mechanisms Determining Structure and Properties of Brazing Systems in Which Compounds Might Form

It is perhaps interesting to discuss briefly the mechanisms which determine the structure and properties of brazed joints in base metal-filler metal systems in which intermetallic compounds might form, based upon the experimental work described herein and in previous reports and upon such data as have been published in the literature, particularly in the area of soldering.

Reasoning from equilibrium considerations, it might be stated that whether a given element in the filler metal forms an intermetallic compound with a given element E in the base metal at a given brazing temperature depends upon the relative values of the free energy of formation of the compound, and the partial molar free energy of solution of the element E in the filler metal. If the former is lower than the latter, the compound will not form; if the reverse is true, the compound will form. The concentration at which the free energies are equal theoretically defines the "critical concentration limit." These thermodynamic concepts determine the equilibrium phase diagram and would determine the structure and composition of the brazed joint at brazing temperature, if brazing were an equilibrium process.

Continuing this analysis, the structure of the brazed joint at room temperature depends upon changes which occur during cooling from the brazing temperature. Thus, new phases may appear which were unstable at the brazing temperature; and if the solubility of base metal in filler metal decreases with temperature, dendrites of base metal saturated with filler metal may precipitate at the base metal-filler metal interface, or within the filler-metal layer, as happens in the brazing of steel with copper.

Since brazing is not an equilibrium process, the above analysis

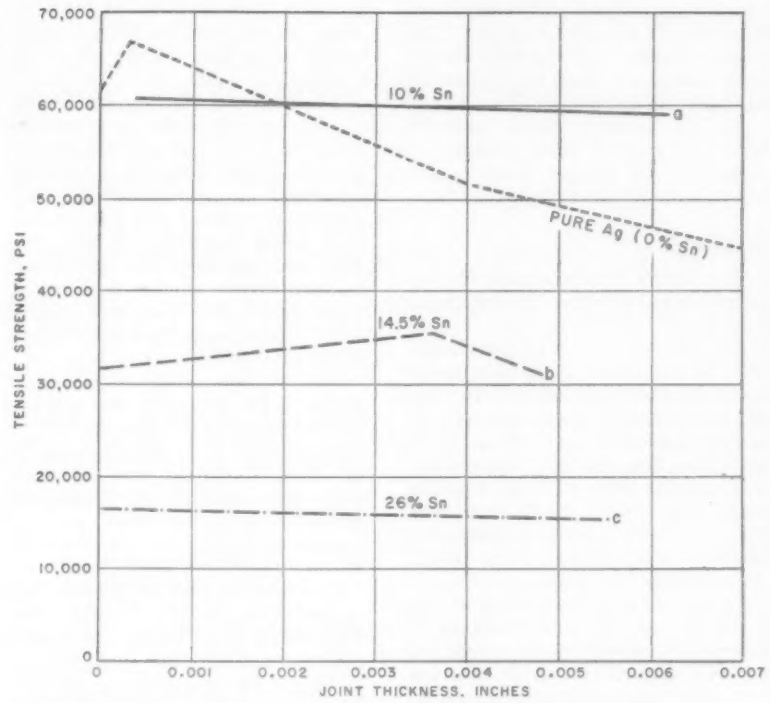

Fig. 16—Tensile strength-joint thickness curves of low-carbon (1020) steel joints brazed with Ag-Sn alloys: (a) 90.0% Ag – 10.0% Sn alloy; (b) 85.5% Ag – 14.5% Sn alloy; (c) 74.0% Ag – 26.0% Sn alloy.

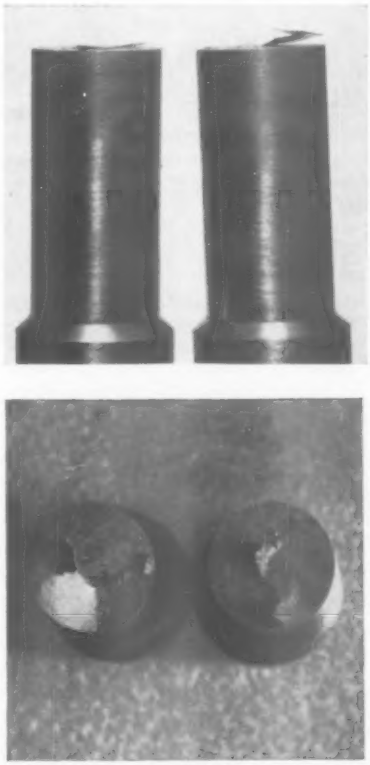

Fig. 17—Fractured low-carbon steel tensile bar brazed with 74% Ag – 26% Sn alloy

is seen to be an oversimplification. Especially in induction brazing, where the filler metal enters the capillary and solidifies within a minute or two, all the interaction between base metal and filler metal is limited primarily to the interface, and local concentrations and temperatures may be far from average. The case of silver-silicon filler metal for the brazing of steel is seen to be especially interesting; in this case, the temperature at the base metal-filler metal interface rose much higher than the average brazing temperature, possibly above the melting point of iron, because of the highly exothermic nature of the reaction: Fe + Si = FeSi + 19,200 cal. In addition, the structure of the joint was not uniform throughout the entire capillary, since the high affinity of silicon for iron exhausted the filler metal of silicon before the capillary had been completely filled.

The effect of time during the brazing process is potent in so far as it dictates the degree of departure from equilibrium.

The strength of a brazed joint may be dependent upon:

1. The presence or absence of intermediate phases, as shown by all the work herein presented.
2. The bulk properties (me-

chanical properties and thermal coefficient of expansion) of the filler layer or layers and the base metal, both absolutely and in relation to each other.

3. The bonding force between base metal and filler metal, irrespective of phases formed and above items (1) and (2).

Summary

A program to investigate the occurrence and effects of intermetallic compound formation in brazed joints has been completed, utilizing low-carbon steel as base metal and the following as filler alloys: Ag-Si, Ag-Zn and Ag-Sn alloys. These alloys were chosen because silver and iron are mutually immiscible and do not offer complicating interactions. Also, silicon, zinc and tin can all form intermetallic compounds with iron and have widely different affinities for iron.

In brazing steel with Ag-Si alloys, a silicon content in the silver as low as 1% results in the formation of an intermediate phase layer at the base metal-filler metal interface which reduces joint strength. The formation of the iron silicides liberates considerable heat at the interface, which raises the temperature locally, possibly to the melting point of iron. The affinity of iron for silicon is so great that all the silicon was practically exhausted from the filler metal before the capillary in abutting $^3/_4$-in. diameter bars was filled.

From work on the brazing of steel with Cu-Fe-B filler metals, it is seen that the critical concentration limit of B in molten Cu is somewhat higher than the critical concentration limit of Si in molten Ag. This relationship could be anticipated since the electropositive Cu has a certain affinity for the electronegative B; at least the affinity of B for liquid Cu is much higher than the affinity of Si for liquid Ag.

In brazing steel with Ag-Zn alloys, variation in zinc content from 5 to 25% did not affect joint strength, and no metallographically observable intermetallic compounds formed at the base metal-filler metal interface. A 50% Ag – 50% Zn alloy formed no intermetallic compounds at the base metal-filler metal interface but yielded weak joints due to the brittle nature of the filler metal.

In brazing steel with Ag-Sn alloys, joint strength was lowered continuously by increasing the tin content from 10 to 26%. No effect of joint thickness was observed over the range of thickness from essentially zero to 0.006 in.

Acknowledgments

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References

1. N. Bredzs and H. Schwartzbart, "Metallurgy of Bonding in Brazed Joints, Part I," THE WELDING JOURNAL, **37** (11), Research Suppl., 493-s to 498-s (1958).

2. N. Bredzs and H. Schwartzbart, "Metallurgy of Bonding in Brazed Joints, Part II," *Ibid.*, **38** (8), Research Suppl., 305-s to 314-s (1959).

3. *Metals Handbook*, ASM, 1948 Edition.

4. J. Weiss, "Introduction to the Study of Metallic Cementation." *Revue de Metallurgie* **XXI,** 18–41 (1924).

5. T. B. Crow, "Some Experiments on the Soft Soldering of Copper." *J. Inst. Metals*, **35,** 55–70 (1926).

6. S. J. Nightingale, "Soft Solders and Soldered Joints," Part I. *Brit. Non-Ferrous Metals Research Assoc.*, Jointing of Metals, Research Report B.R.A. 214 (December 1929).

7. S. J. Nightingale and D. F. Hudson, "Tin Solders: A Modern Study of the Properties of Tin Solders and Soldered Joints." *Brit. Non-Ferrous Metals Research Assoc.*, Chemical Publishing Company, Brooklyn (1942).

8. A. Greigh and H. Heape, "Contribution to Discussion on Crow's Paper, Fluxes for Soft Soldering." *Trans. Faraday Soc.*, **20,** 206–207 (1924).

9. J. H. S. Dickenson, "Note on a Failure of Manganese-Bronze." *J. Inst. Metals*, **24,** 315 (1920).

10. R. Chadwick, "The Influence of Surface Alloying on the Strength of Soft-Soldered Joints." *J. Inst. Metals*, **62,** 277–295 (1931).

11. H. Hanemann, "Testing of Soft Solders." *Zeit. Metall.*, **28,** 68–69 (1936).

12. B. W. Gonser and C. M. Heath, "Physical Properties of Soft Solders and Soft Soldered Joints." *Trans. Am. Inst. Mining Met. Engrs.*, **122,** 349–371 (1936).

13. L. E. Rostosky and E. Lüder, "The Elements of the Physical Chemistry of Brazing and Soldering." *Zeit. Metall.*, **21,** 24–26 (1929).

14. S. L. Case, "Monograph on the Brazing of Steel," Army Air Forces Technical Report No. 5602, Air Materiel Command, Wright Air Development Center (January 1947); also "Brazing of Steel," Part III, *Steel Processing*, **36,** 238–243 (1951).

15. R. D. Wasserman and J. Quaas, "Dilution and Diffusion Aspects of Nonfusion Welding." THE WELDING JOURNAL, **30,** 1098–1101 (1951).

16. Hume-Rothery, *Electrons, Atoms, Metals and Alloys*, Philosophical Library, New York, Revised edition, p. 306 (1955).

17. O. Kubaschewski and E. L. Evans, *Metallurgical Thermochemistry*, John Wiley & Sons, Inc., New York (1956).

18. F. Walter, *Zeit. Metall.*, **13,** 225 (1921).

19. F. Weibke and O. Kubaschewski, *Thermochemie der Legierungen*, Berlin (1943).

20. Rudolf Vogel and Walter von Mässenhausen, "Das System Silber-Eisen-Silizium," *Arch. Eisenhüttenwesen*, **27** (2), 143–145 (1956).

21. Y. H. Chou, "Distribution of Certain Alloying Elements Between Liquid Iron and Silver." Doctorate Thesis, Department of Metallurgy, Carnegie Institute of Technology, 1947.

22. H. M. Schadel, J. A. Derge and C. E. Birchenall, "Activity of Liquid Silver-Silicon Alloys." *Trans. AIME*, **188,** 1134 (1950), TP 2911-E.

23. W. Lihl and O. Feischl, "Herstellung und Konstitution der Kupfer-Bor Legierungen." *Metall.*, **8** (1954).

24. N. Bredzs and H. Schwartzbart, "Fundamentals of Brazing." Fifth Year Final Report. Contract No. DA-11-022-ORD-957 (December 1957).

25. K. Weigert, "Constitution and Properties of Ag-Cu-Zn Brazing Alloys," *J. Metals*, **6,** 233–243 (1956).

26. M. Hansen, *Constitution of Binary Alloys*, McGraw-Hill Co., New York, 1958.

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Relationship between nil-ductility transition and various Charpy V-notch transition temperatures, including the 15-mil lateral-expansion transition temperature, is examined

BY J. H. GROSS

ABSTRACT. A number of NRL reports based on drop-weight test investigations have indicated that Charpy V-notch transition temperatures at a constant energy absorption such as 15 ft-lb do not provide a reliable measure of susceptibility to brittle fracture for steels of different strength and deoxidation practice. Although the NRL reports were generally confirmed by studies conducted at Lehigh University, the latter studies reported that the 15-mil lateral-expansion Charpy V-notch transition temperature appeared promising as an invariant measure of resistance to brittle fracture. Since the NDT determined in the drop-weight test has also been reported to provide a measure of resistance to brittle fracture without special consideration of deoxidation practice or strength, a good correlation between the NDT and the 15-mil lateral-expansion Charpy V-notch transition temperature might be expected. The present paper examines the relationship between the NDT and various Charpy V-notch transition temperatures including the 15-mil lateral-expansion transition temperature.

Data are reported on the NDT and various notch-toughness, notch-ductility and fracture-appearance Charpy V-notch transition temperatures for 11 plain-carbon and high-strength alloy steels in a variety of microstructural conditions. The results indicate that all the various types of Charpy V-notch transition temperatures exhibit a general linear correlation with NDT.

Statistical analysis of the data revealed that Charpy V-notch transition temperatures determined from notch-ductility measurements of the lateral expansion most nearly approached a direct one-to-one correlation with NDT, and that a regression line exhibiting essentially an exact one-to-one correlation was obtained with the 15-mil lateral-expansion Charpy V-notch transition temperature.

Much of the scatter observed in the correlations was attributable to an influence of the heat-affected zone on the behavior of drop-weight test specimens. Anomalous NDT values were observed for steels in the quenched, the quenched and tempered, the prestrained and the prestrained and aged condition. Reliable predictability of the NDT from notch-ductility Charpy V-notch transition temperatures appears promising providing the influence of the heat-affected zone on the drop-weight NDT can be fully understood.

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Introduction

Continued catastrophic failure of service structures has maintained interest in the brittle-fracture problem. A large proportion of this effort has been expended in the development of new tests intended to simulate service behavior. Thus many large semiworks tests incorporating service variables have been proposed and studied. As pointed out by Parker,[1] these tests have indicated the ability of a material to perform in a particular kind of service without failing in a brittle manner. However, it does not appear likely that large test specimens can accurately reproduce the many diversities of service applications. Moreover, extensive correlation studies between different tests have commonly resulted in contradictory conclusions regarding resistance to brittle fracture. These contradictions have usually resulted from indiscriminate use of totally different criteria. Stout and McGeady[2] have stated that the type of specimen tested may be less important than the criterion chosen for interpreting the test results. Thus it appears that a better understanding of existing standard tests is more likely to solve the brittle-fracture problem than the development of more complicated tests that are difficult to interpret.

Of the many tests used to evaluate susceptibility to brittle fracture, probably the simplest, oldest and most widely used is the Charpy test. Both the V-notch and keyhole Charpy tests are currently employed. However, the V-notch test is used almost exclusively in research studies, and acceptance specifications are gradually being changed to V-notch values. Unfortunately, use of the Charpy test for design specifications was for many years limited by a lack of service correlation, the ultimate requirement of the designer. For these reasons, previous and continuing efforts to develop a thorough understanding of the Charpy V-notch test are justified and necessary.

In 1953, Williams and Ellinger[3] reported the first extensive empirical correlation between a brittle-fracture test and service performance. A statistical study of ship failures revealed that the energy absorption in the Charpy V-notch test could be related to the origin, propagation and arrest of brittle fracture in ship plate (ABS Class A). Thus it was possible to specify a test and criterion in designing for resistance to brittle fracture.

In 1952 Puzak, *et al.*,[4] of the Naval Research Laboratory reported two new brittle-fracture tests—the crack-starter explosion-bulge test and the drop-weight test. Both tests evaluate the behavior of steel in the presence of an "ultrasharp" crack, originated during testing in a hard-surfacing weld bead previously deposited on the surface of the specimen. The ability of a highly stressed specimen to exhibit limited plastic deformation without fracture in the presence of an ultrasharp crack was selected as the criterion for susceptibility to brittle fracture on the basis that sharp cracks and small amounts of plastic deformation at positions of unfavorable design do occur in large welded structures.

Three transition temperatures were defined for the crack-starter explosion-bulge test—NDT (nil-ductility transition), FTE (fracture transition for elastic loading) and FTP (fracture transition for plastic loading). In the drop-weight test,

Table 1—Chemical Composition and Heat Treatment of Steels

Steel	Steel grade and designation	Chemical composition, % C	Mn	P	S	Si	Ni	Cr	Mo	V	Ti	Cu	B	Total Al	Austenitizing temperature, °F	Stress-relieving or tempering temperature, °F
A	A-285-C AR	0.20	0.49	0.01	0.018	0.04	0.04	0.01	0.01	...	...	...	...	0.007	1650	1150
B	A-201-A W	0.13	0.49	0.01	0.025	0.19	0.05	0.01	0.01	...	...	...	...	0.007	1650	1150
C	A-201-A EY	0.14	0.51	0.01	0.033	0.20	...	...	...	...	...	...	...	...	1650	1150
D	A-212-B BR	0.32	0.71	0.02	0.021	0.24	0.02	0.03	0.01	...	...	...	...	0.005	1650	1150
E	48s5-HT E	0.15	1.09	0.03	0.028	0.18	...	...	...	0.09	0.009	...	...	...	1650	1150
F	A-203-D ER	0.17	0.59	0.01	0.026	0.24	3.34	0.06	0.02	...	...	0.70	...	0.024	1650	1150
G	HY-65 G	0.12	0.48	0.01	0.032	0.21	2.16	...	0.39	...	...	...	...	...	1750	1200
H	A-302-B OR	0.21	1.20	0.01	0.028	0.25	0.15	0.07	0.50	...	...	...	...	0.029	1650	1150
I	A-302-B TY	0.19	1.26	0.02	0.025	0.22	...	...	0.46	...	...	...	...	...	1650	1150
J	A-387-D SY	0.11	0.37	0.01	0.010	0.26	0.16	2.20	0.96	...	...	...	...	0.008	1700	1350
K	"T-1" R	0.15	0.93	0.01	0.022	0.27	0.89	0.48	0.44	0.06	...	...	0.0031	...	1700	1200

Table 2—Code to Heat-treating Conditions of Steels

Condition	Treatment
1	As received[a]
2	Furnace cooled
3	Normalized
4	Normalized and stress relieved
5	Oil quenched
6	Oil quenched and tempered
7	Brine quenched
8	Brine quenched and tempered
9	Normalized, stress relieved, prestrained 5%
10	Normalized, stress relieved, prestrained 5%, aged 500° F—2 hr

[a] Steels A, C, D, F, H, I—hot rolled; Steel K—mill quenched and tempered.

which is considerably simpler to perform, only the NDT is determinable. The NDT is defined as "the temperature below which the steel loses all ability to deform in the presence of a sharp crack (i.e., nil ductility, % elongation = 0)." The different transition criteria were reported to correlate with various other brittle-fracture tests. However, the most important correlation was between NDT and fracture initiation in the NBS study.[3] ABS Class A steels (rimmed and semi-killed) absorbed an average of 4 to 6 ft-lb in the Charpy V-notch test at the NDT temperature compared to 5 to 7 ft-lb at the ship-failure temperature. Thus it was concluded that "source-plate" service performance for these steels was predictable from the NDT.

The preceding investigations on ABS Class A steels suggested that an energy absorption of 10 to 20 ft-lb in the Charpy V-notch test provided adequate resistance to brittle fracture for conventional ship-plate applications. Consequently, service transition temperatures were recommended on this basis. However, further NRL studies[5-8] indicated that the NDT for fully killed and high-strength alloy steels correlated with much higher energy absorptions than the 4 to 6 ft-lb average reported for ABS Class A steel. Therefore, on the basis of the drop-weight test, no single invariant energy criterion can be employed in interpreting Charpy V-notch test data. Moreover, a different energy criterion would be necessary for each type of steel and, depending on reproducibility, each heat of steel and each condition of heat treatment. Thus a drop-weight test for the NDT could be requisite to each Charpy V-notch transition-temperature determination.

This controversial situation has been partially reconciled by the suggestion[9] that a single invariant measure of notch ductility rather than variable energy absorption can be used for determining the Charpy V-notch transition temperature. This recommendation was based on the observation that energy absorption in a notched-bar test is the integrated product of the force (strength of the steel) and displacement (notch ductility of the steel). Thus for a constant notch ductility, higher-strength steels should exhibit greater energy absorption than lower-strength steels. Consequently, notch ductility may be better determined by a direct measurement of this property, viz., the lateral expansion on the compression side of the Charpy V-notch test specimen; rather than indirect measurement of notch ductility from the energy absorption. A comprehensive investigation of the energy-absorption—notch-ductility relationship in the Charpy V-notch test revealed an increase in energy absorption with tensile strength for any constant value of notch ductility (lateral expansion). A lateral expansion of 15 mils appeared to be a reasonable level of notch ductility to require of all structural materials regardless of strength. To a first approximation, the use of this criterion appears to eliminate the problem of adjusting the energy absorption as the strengths of the steels change.

The lateral expansion is believed to be a direct measure of the notch ductility in the Charpy V-notch test. The drop-weight test likewise is considered a test for ductility-transition behavior. Therefore, a correlation between these two criteria which is unaffected by strength might be expected. This paper is intended to examine this hypothesis as well as relate drop-weight-test behavior to the transition-temperature criteria commonly determined for the Charpy V-notch test.

Experimental Procedure

Steels

Eleven heats of nine different structural steels were tested, including four plain-carbon steels of varying carbon content and deoxidation practice and seven high-strength alloy steels representing most of the commonly encountered structural plate materials. The chemical compositions and heat treatments are reported in Tables 1 and 2.

Table 3–Experimental Test Results for Steels

Steel and heat-treatment code		Tensile properties				Drop-weight test data					Charpy V-notch transition-temperature data						
		Yield strength (0.2% offset), ksi	Tensile strength, ksi	Elong. in 1 in., %	Red. of area, %	Stop dist., in.	NDT, F	Energy at NDT, ft-lb	Lat. Exp. at NDT, mil	Fibrous fracture, at NDT, %	10 ft-lb, F	15 ft-lb, F	20 ft-lb, F	10 mil, F	15 mil, F	20 mil, F	50% fibrous fracture, F
A-285(AR)	A-1	28.9	60.2	33.5	64.0	0.30	+30	9	11	4	+48	+68	+80	+22	+48	+62	+135
	2	34.2	58.8	37.0	64.2	0.25	+30	7	11	3	+54	+76	+90	+28	+50	+66	+146
	3	37.4	62.3	36.0	65.8	0.30	+20	8	13	4	+30	+46	+60	+10	+26	+38	+106
	4	36.8	61.4	36.5	67.5	0.30	+20	7	12	4	+34	+48	+58	+12	+30	+40	+98
	9	59.2	69.2	27.0	65.0	0.30	+50	5	8	1	+80	+94	+102	+60	+80	+92	+128
	10	61.8	70.9	23.5	61.3	0.30	+70	6	9	6	+90	+106	+120	+72	+90	+102	+170
A-201(W)	B-2	31.6	53.3	38.0	65.9	0.30	+10	6	12	2	+32	+46	+56	+2	+18	+30	+102
	3	29.8	54.6	38.5	67.2	0.30	0	7	13	4	+22	+42	+52	+10	−8	+25	+75
	4	29.1	55.8	37.0	67.7	0.25	0	5	11	2	+42	+60	+72	−2	+24	+44	+108
	9	54.8	65.6	25.5	67.4	0.30	+10	7	10	5	+45	+58	+66	+22	+40	+54	+78
	10	58.2	66.1	24.5	64.5	0.30	+20	4	7	2	+58	+72	+80	+36	+54	+65	+86
A-201(EY)	C-1	37.7	65.2	33.5	65.1	0.30	+10	10	15	12	+10	+26	+42	0	+10	+24	+80
	2	38.0	62.8	33.0	61.4	0.30	+30	7	14	4	+52	+68	+80	+10	+32	+50	+140
	3	45.2	67.6	32.5	66.0	0.30	0	13	18	15	−10	+6	+18	−20	−8	+4	+65
A-212(BR)	D-1	41.8	83.4	28.0	55.8	0.30	+50	9	11	6	+56	+80	+98	+44	+68	+88	+142
	2	43.0	77.6	26.5	47.9	0.30	+50	8	14	4	+64	+88	+106	+28	+55	+76	+158
	3	48.9	84.0	28.0	57.6	0.30	+40	15	18	10	+20	+42	+60	−10	+25	+46	+112
	4	46.6	80.4	32.0	60.0	0.30	+30	9	15	5	+32	+50	+62	+14	+32	+48	+110
	5	60.6	95.4	25.5	55.2	0.30	+80	11	16	12	+72	+104	+120	+35	+76	+100	+132
	6	59.3	93.6	27.5	63.9	0.30	+40	13	16	10	+15	+50	+72	+5	+34	+56	+108
	9	77.0	86.0	23.0	51.3	0.30	+90	21	25	13	+56	+72	+88	+50	+62	+76	+138
	10	83.4	90.0	20.5	54.2	0.30	+100	15	20	16	+72	+100	+120	+62	+82	+102	+156
48s5(E)	E-2	48.4	69.0	34.5	72.0	0.30	0	42	46	8	−40	−28	−18	−48	−36	−28	+38
	3	50.9	72.6	36.5	73.6	0.30	−10	45	63	10	−50	−40	−34	−55	−44	−38	+40
	4	48.3	71.9	34.0	73.3	0.30	+10	75	61	28	−52	−34	−20	−58	−42	−32	+30
	5	61.0	92.0	27.5	74.2	0.30	0	60	53	20	−54	−45	−36	−50	−42	−34	+30
	6	72.7	90.2	30.5	73.0	0.30	+10	60	52	13	−60	−44	−30	−55	−40	−26	+56
	9	64.4	76.5	28.5	72.0	0.30	+20	32	32	10	−12	+2	+10	−12	+2	+10	+60
	10	71.3	76.2	27.0	71.0	0.30	+20	14	17	7	+2	+22	+32	−4	+15	+28	+60
A-203(ER)	F-1	52.5	80.9	29.5	63.1	0.30	−60	8	11	1	−50	−28	−10	−62	−40	−22	+80
	2	55.6	75.4	32.0	63.0	0.30	−70	10	14	5	−70	−50	−32	−82	−66	−52	+40
	3	60.6	81.5	29.0	66.6	0.30	−100	23	24	6	−150	−128	−110	−150	−130	−112	−34
	4	60.5	79.0	33.5	69.2	0.30	−90	34	34	10	−138	−128	−118	−138	−112	−94	−28
	5	60.6	96.0	28.0	66.6	0.30	−90	23	21	11	−140	−114	−100	−134	−162	−150	−66
	6	70.6	88.5	31.5	75.7	0.30	−130	38	31	9	−194	−168	−152	−188	−128	−118	−30
	9	70.4	82.4	29.0	69.0	0.30	−150	3	3	0	−102	−86	−74	−98	−82	−70	−10
	10	77.4	84.4	26.0	67.6	0.30	−140	2	2	0	−64	−50	−40	−64	−50	−40	+16
HY-65(G)	G-2	61.7	84.1	29.0	65.4	0.30	−70	8	10	1	−32	−5	12	−52	−20	0	+100
	3	66.3	95.2	25.0	68.6	0.35	−60	13	13	2	−76	−50	−30	−76	−50	−30	+45
	4	95.4	108.0	25.0	69.2	0.35	−80	10	8	1	−85	−66	−52	−75	−58	−45	+48
	5	92.2	128.0	20.5	68.2	0.35	−60	23	16	5	−154	−102	−72	−94	−64	−44	+8
	6	102.0	114.0	23.5	70.6	0.35	−50	37	25	6	−132	−110	−92	−108	−80	−64	+18
	7	112.0	154.0	18.0	63.2	0.35	−90	20	11	10	−180	−112	−88	−96	−66	−34	−40
	8	137.0	142.0	20.0	67.8	0.40	−80	12	7	1	−100	−68	−50	−58	−36	−18	+34
A-302(OR)	H-1	81.4	102.0	22.5	59.2	0.35	+50	17	19	15	+14	+38	+60	+14	+34	+52	+102
	2	48.4	85.2	27.5	57.0	0.30	−20	12	15	8	−28	−4	+14	−42	−20	0	+46
	3	56.8	93.3	24.5	60.6	0.30	−30	12	13	4	−40	−12	+4	−44	−22	−4	+38
	4	62.9	89.8	28.0	64.1	0.30	−40	18	19	10	−70	−48	−32	−70	−52	−36	+10
	5	92.4	130.0	20.0	61.3	0.35	+10	16	13	8	−28	+6	+30	−6	+20	+40	+54
	6	97.6	112.0	22.0	64.9	0.35	−30	25	21	20	−100	−66	−45	−78	−52	−34	0
	7	147.0	202.0	15.0	50.8	0.40	0	15	6	12	−60	−2	+60	+68	..	..	+70
	8	118.0	126.0	21.0	64.8	0.40	−140	20	15	23	−182	−158	−140	−166	−140	−120	−124
	9	87.0	92.5	22.0	61.8	0.30	+10	21	21	15	−50	−14	+6	−40	−14	+6	+34
	10	93.6	98.0	19.5	61.6	0.30	+30	24	24	20	−18	+2	+20	−18	+2	+20	+52
A-302(TY)	I-1	71.3	104.0	18.5	50.5	0.30	+20	13	14	20	−5	+30	+44	0	+24	+40	+44
	2	58.8	86.3	28.0	54.4	0.30	−40	12	15	10	−50	−26	−5	−60	−40	−25	+2
	3	62.8	96.0	23.0	57.4	0.30	−30	13	13	15	−52	−20	+4	−42	−20	0	+16
A-387(SY)	J-7	130.0	173.0	17.0	66.3	0.35	−30	19	7	2	−100	−58	−24	+2	+30	+52	+80
	8	85.8	101.0	26.0	79.8	0.30	−80	120	62	75	−190	−160	−144	−160	−142	−130	−88
"T-1"(R)	K-1	106.0	121.0	20.5	68.5	0.35	−100	33	28	40	−178	−162	−148	−170	−152	−134	−88
	7	143.0	190.0	15.0	54.3	0.40	−30	20	10	32	−160	−84	−28	−30	..	..	−14
	8	133.0	140.0	18.0	63.4	0.35	−60	27	17	29	−200	−126	−92	−100	−70	−48	−36

Note: Heat treatments 2 through 8 were performed in the Laboratory to provide a variety of microstructures. Therefore, the resultant mechanical properties of the steels may not conform to ASTM specifications or to manufacturers' published data.

Heat Treatment and Specimen Preparation

All material was received as 1-in.-thick plate stock. Double drop-weight-test specimens, $3^1/_2$ x 18 x 1 in., were cut parallel to the principal rolling direction. After drop-weight testing, broken pieces of the most brittle specimens which had undergone essentially no plastic deformation were split into two $^1/_2$-in.-thick plates from which longitudinally-oriented Charpy V-notch and half-size tension-test specimens were machined. The Charpy test specimens were V-notched in the plate-thickness direction.

All heat treatments were performed on individual drop-weight-test specimens. The various heat treatments were intended to produce the widest possible range of microstructures and strengths. High strengths were obtained by brine quenching or oil quenching. The suitability of the accelerated-cooling treatments for each steel was established by heat treating sample specimens and determining the uniformity of hardness through the thickness of the plate. Full hardening throughout the section was achieved by brine quenching only in the high-hardenability materials. Oil quenching produced a substantial and uniform increase in hardness through the plate thickness on all materials, and was employed on most of the low-hardenability and several of the high-hardenability steels.

The effect of cold forming during fabrication was simulated for a number of the steels by tension prestraining the drop-weight-test specimens 5% after normalizing and stress relieving. The highest-strength steels were not included since the prestraining load exceeded 300,000 lb and a larger testing machine could not be used with a standard-sized drop-weight specimen due to difficulties in gripping the specimens. The effect of strain-aging was studied by prestraining 5% followed by aging at 500° F for 2 hr.

After the appropriate treatments were completed, the drop-weight specimens were ground to remove surface scale, and the crack-starting weld bead was deposited using the special hard-surfacing electrodes. Ambient-temperature aging effects were standardized by maintaining a one-week treatment-to-testing schedule.

Testing Techniques

Tension and Charpy V-notch tests were performed in the conventional manner. However, published details of the drop-weight testing procedure over a wide range of strengths and thicknesses were not available at the time the tests were conducted; although information on "normalization" of the drop-weight test has recently been published.[10] Therefore, a number of exploratory tests were conducted to determine the effect of several testing variables. Those of particular interest involved the impacting energy and the stop distance. From a limited study it was concluded that variation in impacting energy produced essentially no change in the NDT providing the specimen was always driven to the stop. Thus the full impacting energy of 1200 ft-lb (150 lb weight and 8 ft drop height) was employed on all specimens which could be deformed to the stop by the available energy. Certain heat treatments of the high-strength steels produced strength levels which required greater impacting energies. A second apparatus with an impacting energy of 3000 ft-lb (187.5 lb weight and 16 ft drop height) was used to test drop-weight specimens treated to these high strengths.

The stop distance was also varied from 0.25 to 0.40 in., depending on the yield strength of the material, rather than being maintained at the standard 0.30 in. Since the drop-weight test is intended to require a small amount of plastic deformation without brittle fracture in the presence of a dynamic crack, it appeared logical to require the same amount of plastic deformation of each steel, regardless of strength, by varying the stop distance. The appropriate stop distance was established for each drop-weight test series by slow bending one specimen from each test series and determining the yield strength in bending from an autographically recorded load-deflection diagram. Using ASTM A 201 as the yield-strength standard for the conventional 0.3-in. stop distance, corrections in the stop distance from −0.05 to +0.15 in. were introduced depending on the yield strength. Subsequent

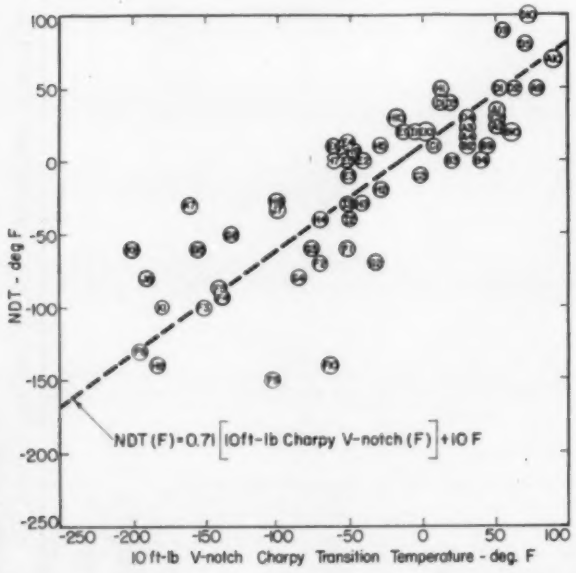

Fig. 1—Relationship between the drop-weight NDT and the 10 ft-lb Charpy V-notch transition temperature

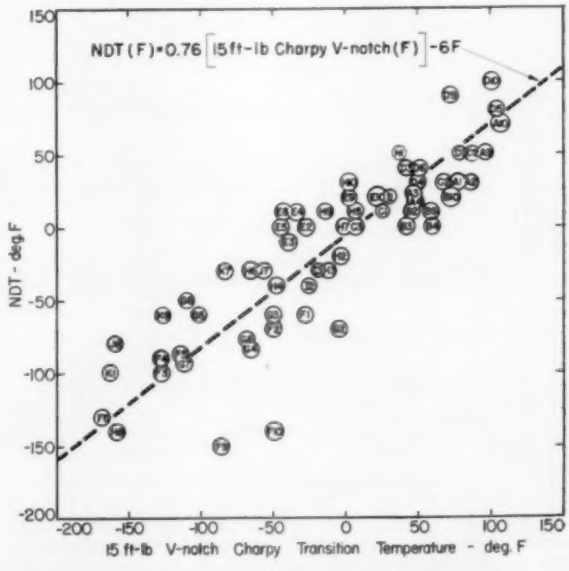

Fig. 2—Relationship between the drop-weight NDT and the 15 ft-lb Charpy V-notch transition temperature

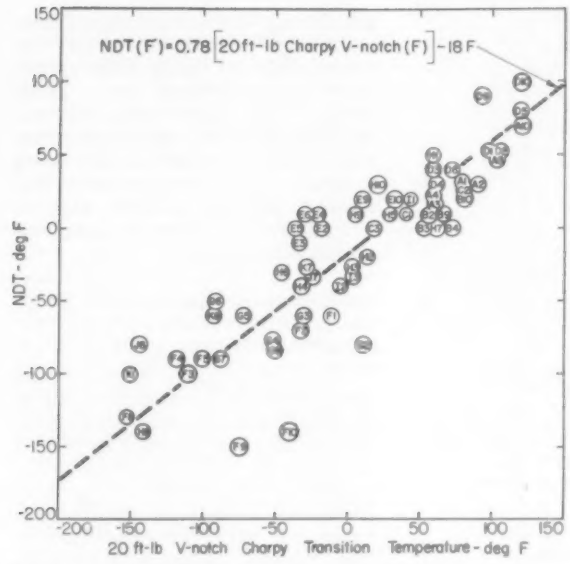

Fig. 3—Relationship between the drop-weight NDT and the 20 ft-lb Charpy V-notch transition temperature

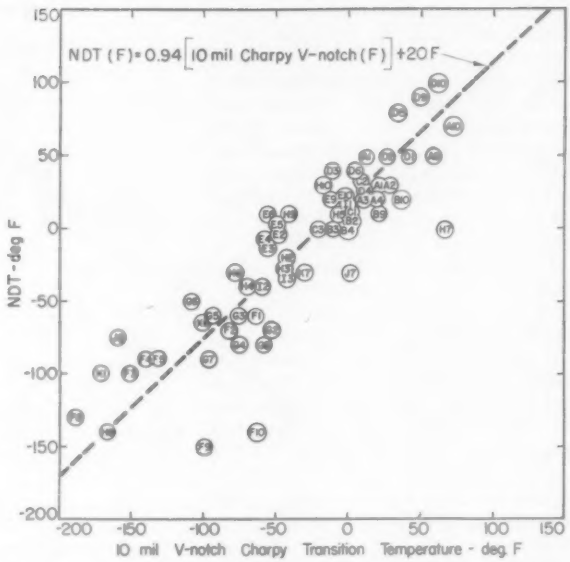

Fig. 4—Relationship between the drop-weight NDT and the 10-mil Charpy V-notch transition temperature

studies have indicated that variations in the stop distance do not change the NDT noticeably except when unrealistically small values are employed. However, the author believes this correction provides a more uniform basis for testing.

The NDT was determined by testing 10 drop-weight specimens over an appropriate temperature range. Twenty-four Charpy V-notch test specimens were broken to define the Charpy V-notch transition curve. Tensile values are the average of duplicate tests.

Transverse sections were machined from drop-weight test specimens, that had failed in a brittle manner, through the hard-surfacing bead about $^3/_4$ in. away from the fracture surface. Vickers hardness surveys at 0.01-in. intervals were conducted in the thickness direction of plate from the weld metal through the heat-affected zone and ending in the unaffected base metal. The same areas were also examined metallographically.

Standard statistical methods were employed in determining the statistical correlations between the NDT and the various Charpy V-notch transition temperatures.

Results and Discussion

The results of the tension, drop-weight and Charpy V-notch tests are presented in Table 3 for the 11 steels investigated. For each steel and condition, the 10, 15 and 20 ft-lb Charpy V-notch transition temperatures were determined from the energy absorption–temperature curves; the 10-, 15- and 20-mil

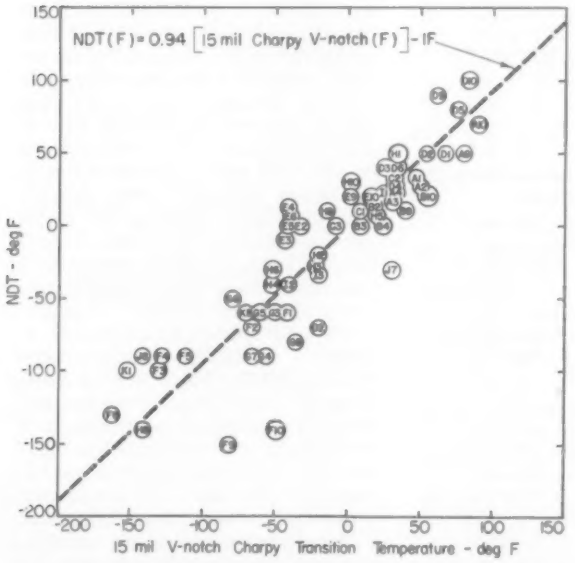

Fig. 5—Relationship between the drop-weight NDT and the 15-mil Charpy V-notch transition temperature

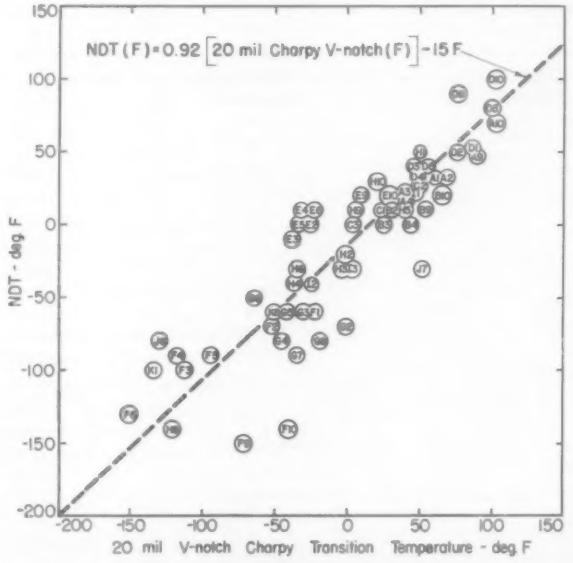

Fig. 6—Relationship between the drop-weight NDT and the 20-mil Charpy V-notch transition temperature

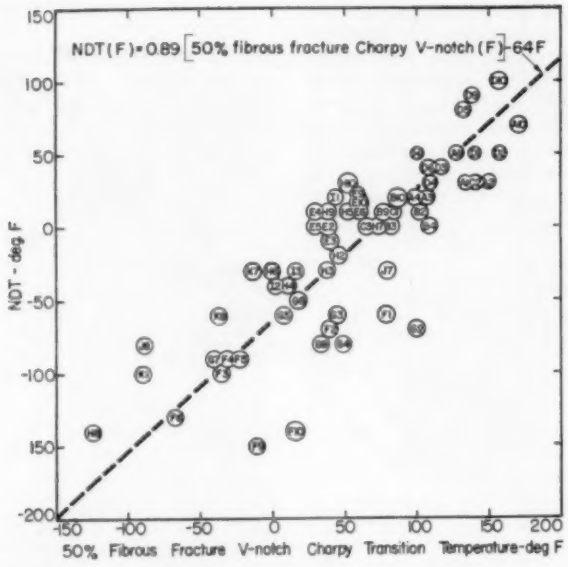
NDT (F) = 0.89 [50% fibrous fracture Charpy V-notch (F)] - 64 F
NDT - deg F
50% Fibrous Fracture V-notch Charpy Transition Temperature-deg F

Fig. 7—Relationship between the drop-weight NDT and the 50% fibrous-fracture Charpy V-notch transition temperature

Charpy V-notch transition temperatures from the lateral expansion–temperature curves and the 50% fibrous-fracture Charpy V-notch transition temperature from the fracture appearance–temperature curve.

At the NDT temperature, the corresponding values of energy absorption, lateral expansion and fibrous fracture were determined from the appropriate Charpy V-notch transition – temperature curves. These values are presented for comparison with similar energy-absorption values reported by NRL.[3-6] The NRL values of Charpy V-notch energy absorption at NDT for various steels have been accepted in many quarters as the level of energy absorption that should be used in determining the Charpy V-notch transition temperature for a particular grade of steel and, to a lesser extent, for classes of steel such as semikilled or killed. This is a questionable practice because variations in chemical compositions within grade limits and differences in microstructure result in wide variations in the Charpy V-notch energy absorption at NDT as illustrated in Table 3. Moreover, as pointed out by Puzak and Pellini,[3] similar differences in energy-absorption do not correspond to similar differences in the Charpy V-notch transition temperature from steel to steel or between different heats and microstructural conditions for a given steel. Thus specification of the NDT from the Charpy V-notch test will probably be realized only when a direct one-to-one correlation between NDT and a certain type of Charpy V-notch transition temperature is established.

Table 4—Regression Equations Relating NDT and Various Charpy V-notch Transition Temperatures

Charpy V-notch transition-temperature criterion	Standard-regression equation	Orthogonal-regression equation
	Notch-toughness (energy absorption) criteria	
10 ft-lb	NDT (F) = 0.64 [10 ft-lb Charpy V-notch T.T. (F)] +8 F	NDT (F) = 0.71 [10 ft-lb Charpy V-notch T.T. (F)] +10 F
15 ft-lb	NDT (F) = 0.69 [15 ft-lb Charpy V-notch T.T. (F)] −7 F	NDT (F) = 0.76 [15 ft-lb Charpy V-notch T.T. (F)] −6 F
20 ft-lb	NDT (F) = 0.71 [20 ft-lb Charpy V-notch T.T. (F)] −18 F	NDT (F) = 0.78 [20 ft-lb Charpy V-notch T.T. (F)] −18 F
	Notch-ductility (lateral expansion) criteria	
10 mil	NDT (F) = 0.84 [10 mil Charpy V-notch T.T. (F)] +16 F	NDT (F) = 0.94 [10 mil Charpy V-notch T.T. (F)] +20 F
15 mil	NDT (F) = 0.83 [15 mil Charpy V-notch T.T. (F)] −2 F	NDT (F) = 0.94 [15 mil Charpy V-notch T.T. (F)] −1 F
20 mil	NDT (F) = 0.82 [20 mil Charpy V-notch T.T. (F)] −16 F	NDT (F) = 0.92 [20 mil Charpy V-notch T.T. (F)] −15 F
	Fracture-appearance (fibrous fracture) criterion	
50% fibrous fracture	NDT (F) = 0.75 [50% Fibrous Fracture T.T (F)] −56 F	NDT (F) = 0.89 [50% Fibrous Fracture T.T (F)] −64 F

Relationship Between NDT and Charpy V-notch Transition-temperature Criteria

The relationship between the drop-weight NDT and the various Charpy V-notch transition-temperature criteria are depicted in Figs. 1 through 7. The distribution of points on the curves clearly illustrates the general interrelation between the NDT and all of the various Charpy V-notch transition-temperature criteria. The scatter is typical of correlations between brittle-fracture tests. The precision in determining the NDT or the various Charpy V-notch transition temperatures is about ±10° F indicating that a perfect correlation would exhibit scatter as great as ±15° F.

The data for Figs. 1 through 7 were analyzed statistically to determine the standard linear-regression equations for the prediction of the NDT from Charpy V-notch values. The orthogonal-regression equation relating the NDT and the various Charpy V-notch transition temperatures was also calculated. The resulting equations are listed in Table 4. An orthogonal-regression analysis does not assume either variable to be correct and the resultant equation minimizes the error in the data points normal to the line of the equation, whereas a standard-regression analysis assumes the independent variable, in this case the Charpy V-notch transition temperature, to be correct and the resultant equation minimizes the error in the dependent variable, in this case the NDT. An examination of Table 4 indicates that the orthogonal-regression equations more nearly approach a one-to-one correlation between NDT and the various Charpy V-notch transition temperatures wherein NDT (F) = 1.00 [Charpy V-notch transition temperature (F)] ± 0. Thus the equations of the lines shown on Figs. 1 through 9 and the equations selected for further analysis were the orthogonal-regression equations. Although the orthogonal-regression analysis does not lend itself to calculation of confidence limits, the one-sigma limits were estimated to range from

±50° F for the NDT vs. 15-mil Charpy V-notch transition-temperature correlation to ±65° F for the NDT vs. 50% fibrous-fracture Charpy V-notch transition temperature. Thus the reliability of the correlations is quite similar.

The orthogonal-regression lines for the various Charpy V-notch transition-temperature criteria are compared in Figs. 8 and 9 with a line of perfect one-to-one correlation. Figure 8 and Table 4 show that the slope of the regression lines for the energy-absorption criteria are essentially parallel to each other but with slopes that are considerably less than unity. Thus Charpy V-notch transition temperatures based on energy absorption tend to be lower at low temperatures and higher at high temperatures than the corresponding NDT values. Agreement with the NDT can be improved at high transition temperatures by determining the Charpy V-notch transition temperature at lower energy absorptions and vice versa, but only at the sacrifice of poorer agreement at the opposite end of the transition-temperature range. The best agreement, over the temperature range studied, between the NDT and a Charpy V-notch energy-absorption transition temperature was obtained for the 15 ft-lb transition-temperature criterion. The observed behavior is undoubtedly not a high or low transition temperature phenomenon but merely reflects the fact that the high transition temperatures were generally obtained for steels exhibiting low tensile strengths while the low transition temperatures were more commonly obtained for heat-treated steels exhibiting relatively high tensile strengths. Since, as previously reported,[9] an increase in tensile strength requires an increase in energy absorption to insure a constant notch ductility, the NDT, which appears to be a notch-ductility test, would be expected to correlate with low Charpy V-notch energy absorptions for low-strength steels and with high Charpy V-notch energy absorptions for high-strength steels.

The regression lines for the lateral-expansion Charpy V-notch transition temperatures (Fig. 9) are also essentially parallel lines but with slopes similar to that of the perfect one-to-one correlation line. Thus, direct correlation between the drop-weight and the Charpy V-notch test appears attainable providing a notch-ductility rather than a notch-toughness criterion is used to determine the transition temperature for the Charpy V-notch test.

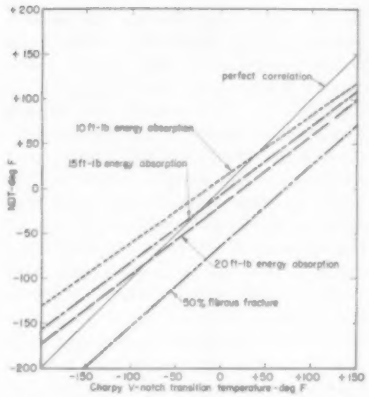
perfect correlation
10 ft-lb energy absorption
15 ft-lb energy absorption
20 ft-lb energy absorption
50% fibrous fracture
NDT - deg F
Charpy V-notch transition temperature - deg F

Fig. 8—Orthogonal-regression lines relating the drop-weight NDT to various notch-toughness Charpy V-notch transition temperatures

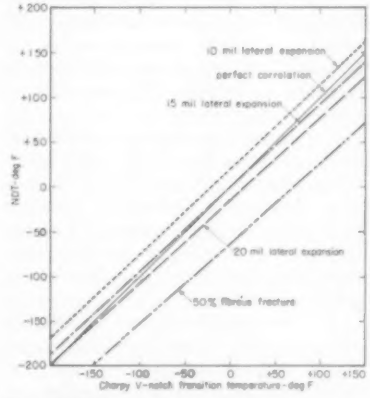
10 mil lateral expansion
perfect correlation
15 mil lateral expansion
20 mil lateral expansion
50% fibrous fracture
NDT - deg F
Charpy V-notch transition temperature - deg F

Fig. 9—Orthogonal-regression lines relating the drop-weight NDT to various notch-ductility Charpy V-notch transition temperatures

The criterion that appears to provide the best direct correlation is the 15-mil lateral-expansion Charpy V-notch transition temperature.

Nevertheless, it should be noted that the 50% fibrous-fracture regression line also exhibited a slope close to unity. Thus, direct prediction of the NDT appears possible from the fracture transition temperature for the Charpy V-notch test. Presumably the large intercept correction (−64° F) for the 50% fibrous-fracture regression line would be greatly reduced if the fibrous-fracture transition temperatures were determined at about 10% fibrous fracture. However, it is important to note that the NDT vs. 50% fibrous-fracture Charpy V-notch transition-temperature correlation exhibited the poorest statistical reliability.

Analysis of Scatter of Data

As noted in the previous discussion, no attempt was made to conduct a rigorous analysis of the "goodness of fit" of the data points to the calculated correlation curves, other than to estimate the sigma limits. A rigorous analysis was not conducted because a number of the heat-treating conditions and, to a lesser extent, certain steels were associated with the data points exhibiting most of the scatter. Elimination of these values would result in considerable improvement of all the NDT-Charpy V-notch transition-temperature correlations.

Among the steels, Steel E (48s-5HT) in all conditions showed a strong tendency toward a high NDT compared to the 15-mil Charpy V-notch transition temperature. This observation has been reported by NRL on several occasions. Steel G (HY65) exhibited NDT values that tended to be consistently low. Examination of the microstructure of the base plate and heat-affected zone failed to provide an obvious answer to the observed behavior and further work should be undertaken.

Among the different microstructural conditions, Conditions 7, 8, 9 and 10 appeared to result in the greatest scatter of data. The best examples of questionable values for the NDT of quenched (Condition 7) and quenched and tempered (Condition 8) steels occurred with the high-hardenability steels that formed martensite on quenching. For example, the NDT for Steel J (ASTM A 387-D) improved only 50° F (−30 to −80° F) from the quenched condition (fully martensitic-tensile strength of 173 ksi) to the quenched and tempered condition (tempered martensite—tensile strength of 101 ksi). For the same conditions, the 15-mil lateral-expansion Charpy V-notch transition temperature improved 172° F (+30 to −142° F). Tempering resulted in a much smaller improvement in the NDT (50° F) than in the 15-mil transition temperature (172° F) because the NDT of the quenched specimen was fictitiously low. This low value occurred because the deposition of the crack-starting bead on the as-quenched drop-weight specimens produced a heat-affected zone that contained notch-tough tempered martensite. Thus the NDT is probably representative of the notch toughness of the heat-affected zone rather than the untempered base plate. The drop-weight test also produced anomalous results when employed on steels that were strained (Condition 9) or strained and aged (Condition 10). Although unusual NDT values were obtained for a number of the steels in the strained or the strained and aged condition, Steel

F (ASTM A 203-D) best illustrates the point. The NDT for Steel F in the normalized and stress-relieved condition was −90° F. Prestraining 5% after normalizing and stress relieving resulted in a 60° F improvement for Steel F to an NDT of −150° F. Prestraining the normalized and stress-relieved Steel F, followed by aging at 500° F for 2 hr, resulted in an improvement in the NDT from −90° to −140° F. On the other hand, the 15-mil lateral-expansion transition temperature for Steel F in the normalized and stress-relieved condition was increased 44° F by prestraining and 80° F by prestraining and aging, and indicated a significant loss in notch ductility due to straining or straining and aging as would normally be expected. Pellini and Puzak[11] have previously noted that drop-weight tests for quenched or quenched- and- tempered material should be prepared by hardening the specimens after depositing the crack-starting weld metal. However, this procedure limits the tempering temperature to values below about 600° F because higher tempering temperatures soften the hard-surfacing crack-starting weld metal and thus alter its crack-starting propensity. They have also cautioned against drop-weight tests on plastically deformed specimens because of possible recrystallization of ferrite in the heat-affected zone. However, the fact remains that quenched or quenched-and-tempered steels as well as cold-formed steels are welded during fabrication and an assessment of the brittle-fracture susceptibility of the composite structure is necessary.

The previously cited limitations on the use of the drop-weight test are related to the effect on drop-weight performance exerted by the heat-affected zone microstructures produced during deposition of the crack-starting weld bead. As previously mentioned, when these anomalous results are omitted a substantially improved relationship between the NDT and the Charpy V-notch ductility-transition temperature is obtained, particularly for the 15-mil lateral-expansion transition temperature. However, the data points eliminated are those associated with large discrepancies in the NDT. The extent to which less drastic changes in microstructure of the heat-affected zone might influence drop-weight performance is not known. The author is of the opinion that a careful analysis of the influence of heat-affected-zone microstructures on drop-weight-test performance will further improve the present correlations and demonstrate that the drop-weight test does not provide information beyond that available from a notch-ductility analysis of Charpy V-notch test data.

Conclusions

A comparison of the drop-weight-test NDT and various Charpy V-notch transition temperatures for 11 structural steels in a variety of microstructural conditions indicates the following results:

1. A general linear correlation exists between the NDT and notch-toughness, notch-ductility and fracture-appearance Charpy V-notch transition temperatures with about the same data-point scatter normally observed in brittle-fracture test correlations.

2. Statistical analysis of the data indicates that Charpy V-notch transition temperatures determined from notch-ductility measurements of lateral expansion provide a more nearly direct (one-to-one) correlation with NDT than do Charpy V-notch transition temperatures determined from notch-toughness measurements of energy absorption.

3. The 15-mil lateral-expansion Charpy V-notch transition-temperature correlation with the NDT exhibited essentially a one-to-one relation.

4. The reliability of the correlations was greatly reduced by the anomalous response of the drop-weight tests for steels in the quenched, the quenched and tempered, the prestrained and the prestrained and aged conditions.

5. For certain microstructural conditions, the behavior of the drop-weight test is strongly influenced by the heat-affected-zone microstructures produced during deposition of the crack-starting weld bead.

6. A highly reliable prediction of the NDT from a notch-ductility Charpy V-notch transition temperature appears promising providing the influence of the heat-affected zone on the drop-weight NDT can be fully understood.

Acknowledgments

The experimental results for this paper were obtained as part of a program sponsored by the Weldability Committee of the Welding Research Council and the author is indebted to the committee for their support and assistance.

The author is also indebted to Robert Schockmel, a Gotshall Scholar in the Graduate School of Metallurgical Engineering, Lehigh University, who was instrumental in gathering many of the experimental data.

References

1. Parker, E. R., *Brittle Behavior of Engineering Structures*, John Wiley and Sons, Inc., 1957.
2. Stout, R. D., and McGeady, L. J., "The Meaning and Measurement of Transition Temperature," THE WELDING JOURNAL, **27** (6), Research Suppl., 299-s to 302-s (1948).
3. Williams, M. L. and Ellinger, G. A., "Investigation of Structural Failures of Welded Ships," Ibid., **32** (10), Research Suppl., 498-s to 527-s (1953).
4. Puzak, P. P., Eschbacher, E. W., and Pellini, W. S., "Initiation and Propagation of Brittle Fracture in Structural Steels," *Ibid.*, **31** (12), Research Suppl., 561-s to 581-s (1952).
5. Puzak, P. P., and Pellini, W. S., "Evaluation of Notch-Bend Specimens," *Ibid.*, **33** (4), Research Suppl., 187-s to 192-s (1954).
6. Puzak, P. P., Schuster, M. E., and Pellini, W. S., "Applicability of Charpy Test Data," *Ibid.*, **33** (9), Research Suppl., 433-s to 441-s (1954).
7. Puzak, P. P., Schuster, M. E., and Pellini, W. S., "Crack-Starter Tests of Ship Fracture and Project Steels," *Ibid.*, **33** (10), Research Suppl., 481-s to 495-s (1954).
8. Puzak, P. P., and Pellini, W. S., "Evaluation of the Significance of Charpy Tests for Quenched and Tempered Steels," *Ibid.*, **35** (6), Research Suppl., 275-s to 290-s (1956).
9. Gross, J. H., and Stout, R. D., "Ductility and Energy Relations in Charpy Tests of Structural Steels," *Ibid.*, **37** (4), Research Suppl., 151-s to 159-s (1958).
10. Puzak, P. P., and Babecki, A. J., "Normalization Procedures for NRL Drop-Weight Test," *Ibid.*, **38** (5), Research Suppl., 209-s to 218-s (1959).
11. Pellini, W. S., and Puzak, P. P., Discussion, "Relative Behavior of Notch-Toughness Tests for Welded Steels," *Ibid.*, **36** (11), Research Suppl., 511-s to 512-s (1957).

Discussion

By P. P. Puzak

In his paper, Dr. Gross has provided interesting and valuable information concerning empirical Charpy V correlations with the drop-weight test. The discusser is gratified to learn that the NRL studies were generally confirmed by the studies conducted at Lehigh University. Discussion of Dr. Gross' paper is prompted by differences of opinion concerning the suggested reliability of using an invariant Charpy V transition criterion for prediction of brittle-fracture potentialities in all steel types.

Any criterion proposed for the prevention of brittle fracture of steel structures must demonstrate direct correlation with a substantial number of service failures in order to be considered valid. The concepts based on NDT have been fully validated not only for the "source-plate" service performance of ship steels,

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which was discussed by the author, but by the equally important service-failure correlations[2] reported for numerous nonship structures including pressure vessels, forgings, machinery components, etc. These service failures bracketed a wide variety of steel compositions, microstructural conditions and strength levels; all of the failures investigated were shown to have been predictable in accordance with drop-weight test determinations of NDT. Accordingly, the modifications in standard drop-weight test procedure employed by the author are unnecessary, and such complications are not recommended by the discusser.

Charpy V-notch energy-absorption values based on NDT correlations have proved to be successful in the prevention of brittle fracture of the heavy-section A302 pressure vessels required for naval aircraft carrier and reactor applications. Approximately twenty different heats of A302 materials were investigated in order to establish the statistical relationships between NDT and Charpy V transition curves. For the 100% confidence limits requested for service at + 40° For higher, index values of 30 ft-lb at +10° F were established for specification purposes. Prior to the utilization of such specifications, two of the A302 pressure vessels built for naval applications failed catastrophically by brittle fractures. Subsequent to the acceptance by the steel mills of the specification (approximately 1955), no additional failures have occurred.

The author has stated that the ±10° F precision in determining NDT or the various Charpy V-notch transition temperatures indicates that a perfect correlation would exhibit scatter as great as ±15° F.

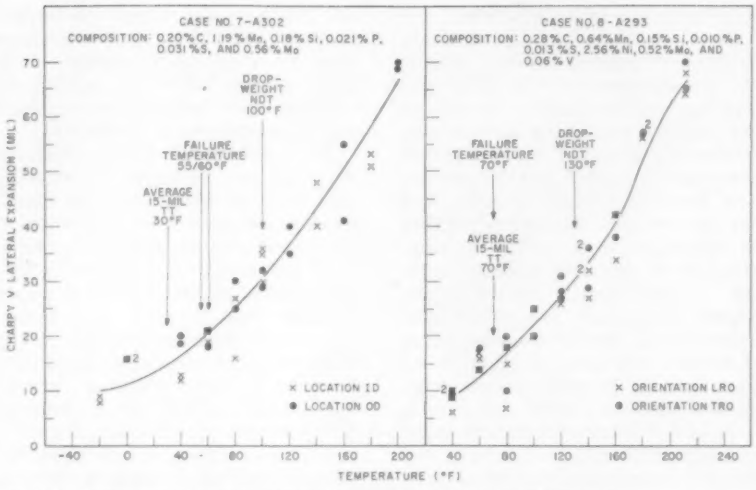
CASE NO. 7-A302
COMPOSITION: 0.20% C, 1.19% Mn, 0.18% Si, 0.021% P, 0.031% S, AND 0.56% Mo
DROP-WEIGHT NDT 100°F
FAILURE TEMPERATURE 55/60°F
AVERAGE 15-MIL TT 30°F
× LOCATION ID
● LOCATION OD
CASE NO. 8-A293
COMPOSITION: 0.28% C, 0.64% Mn, 0.15% Si, 0.010% P, 0.013% S, 2.56% Ni, 0.52% Mo, AND 0.06% V
FAILURE TEMPERATURE 70°F
DROP-WEIGHT NDT 130°F
AVERAGE 15-MIL TT 70°F
× ORIENTATION LRO
● ORIENTATION TRO
CHARPY V LATERAL EXPANSION (MIL)
TEMPERATURE (°F)

Fig. D-1—Two cases of pressure-vessel failure for which a 15-mil Charpy V-notch transition temperature failed to correlate with service performance

The discusser concurs in and would support strongly any criterion which approached such accuracy. Such a correlation could indeed be described as a "direct (one-to-one) correlation." It should be emphasized, however, that the best demonstrated criterion suggested by the author for correlation purposes (15-mil lateral-expansion Charpy V-notch transition temperature) resulted in scatter of such an extent that ". . .one-sigma limits were estimated to range from ±50° F. . ." Such extensive scatter must, admittedly, be considered inadequate because it is too far from any reasonable approach to a direct correlation.

The discusser is firmly convinced that none of the various Charpy V transition criteria proposed to date (energy or ductility) can be used invariantly for prediction of brittle-fracture potentialities in all steel types. Data reported for the nonship-service-failure materials have shown that lateral-expansion correlations are not invariant. In addition, the 15-mil lateral-expansion criterion was shown to have failed to correlate with service performances. The data in Fig. D-1 indicate that the 15-mil lateral-expansion criterion was inadequate to predict the brittle failures developed in two of the pressure vessels investigated by NRL. This being the case, it is considered unwarranted to complicate and confuse Charpy correlations with NDT by unnecessary measurements and calculations which provide an answer no better than that which is read off the energy (ft-lb) scale. Until the development of a better criterion which can be consistently shown to correlate with service, the discusser must conclude that the drop-weight test does provide information which is not available from any analysis limited solely to Charpy V-notch test data.

Discussion

By Louis J. Larson

The author is to be complimented for an excellent analysis and presentation of an enormous amount of data on this subject. Examination of Table 2, bearing in mind the number of individual specimens required on each type of steel for each of the heat-treatment conditions, emphasizes the great number of tests involved. The data presented in these tables will be a valuable fund of information on the notch-toughness of steels.

The author has also done a masterful job in developing the relationship between the various types of data obtained from the Charpy tests and those obtained from the drop-weight tests. His finding that a substantially one-to-one correlation exists between the 15-mil lateral-expansion Charpy V-notch transition temperature and the drop-weight NDT value is particularly attractive. Based on this relationship, simple Charpy specimens can be used instead of drop-weight specimens.

The question then arises—what is the significance of this paper to the engineer? It should be pointed out that in evaluating the author's conclusions from a practical standpoint, the correlation of the Charpy test to the NDT test is not *per se* a measure of its value. The primary objective of all of the many tests which have been devised to determine transition temperatures, is to establish by laboratory tests whether a steel is susceptible to brittle fracture under service conditions. The correlation of the laboratory tests to service behavior

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is the only one of importance.

Based on extensive research work, the NRL developed the drop-weight test for determining the NDT and they are recommending the use of the test for predicting service performance. Puzak *et al.*, in a paper[2] presented in 1958 shows the correlation between service failures and the drop-weight tests of a number of types of steel. A completely satisfactory criterion should establish a temperature above which brittle failures do not occur, and below which brittle fracture types of failures will occur if other conditions leading to brittle failure exist. In the examples cited by Puzak, none of the service structures failed at temperatures above the NDT and for about one-half of the structures, the failure temperature was less than 30° F below the NDT for the material. For these steels, the NDT satisfactorily defines the transition temperature.

However, for slightly over one-half of cases cited, the failures occurred at temperatures considerably below the NDT and in some cases, over 60° F below. One forged ring failed at over 300° F below the transition temperature. The fact that these failures occurred at temperatures considerably below the NDT does not prove that the NDT may not be a suitable criterion since the structures might also have failed at higher temperatures. However, neither can such failures be used to prove the assumption that the NDT is the proper criterion. It is difficult and may require a long time to accumulate enough data from service failures to definitely establish that failures may occur at any temperature up to the NDT.

Even though the NDT correlates with service failures, it appears that it is significant only in determining the temperature below which cracks will propagate after they have been initiated. This is an important phase of the brittle fracture problem but is only one phase. The other important phase is the initiation of the fracture which later becomes a major failure. Among the factors which affect fracture initiation are the presence of a sufficiently sharp crack or defect and the presence of high stresses in the area of the crack. Even after a crack starts, it will not propagate unless the stress in the material is above some critical value. It is doubtful that the NDT values will be influenced in any way by these factors.

Some engineers, particularly those in the structural field, have shown a reluctance to adopt the drop-weight test in appraising the suitability of steel subjected to outdoor temperatures. They point out that on the basis of the NDT values, most of the common structural steels would be unsafe when subjected to normal climatic conditions. Many existing structures are giving perfectly satisfactory service even though they may be exposed to temperatures below the NDT for the steel. Possibly the reason failure does not occur is because the other conditions, such as notch sharpness and stresses at the root of the notch, are not such as to initiate brittle fractures. For practical reasons it may be necessary to take all possible steps to prevent crack initiation rather than specify steels with NDT below minimum operating temperature.

In conclusion, it appears that the author has presented convincing evidence that the expansion measurements on Charpy V specimens can be used to predict the NDT for materials and hence, the Charpy specimens may be just as reliable and certainly more convenient than the drop-weight test for determining the suitability of a steel at any given service temperature. In fact, since the Charpy specimens are not subjected to any heat of welding such as are the drop-weight specimens, it is possible that the Charpy specimens may be more reliable than the drop-weight test for materials which are affected by welding heat. As pointed out by the author, the greatest discrepancies between the Charpy specimens and the drop-weight specimens was for materials which had been heat treated. All available opportunities for correlating the Charpy lateral-expansion values directly with service performance should be exploited, since this is the most important correlation from a practical standpoint.

Author's Closure

The discussions presented by Mr. Larson and by Mr. Puzak are extremely interesting and timely. Since both discussions deal primarily with the probem of applying laboratory brittle-fracture test data to service performance of engineering structures, the author has taken the liberty of preparing a joint reply.

Mr. Puzak contends that the drop-weight NDT correlates better with service performance than any Charpy V-notch transition temperature, including the 15-mil lateral-expansion transition temperature, because the NDT is always above the service-failure temperature, whereas the 15-mil transition temperature may be lower than the service-failure temperature. On the other hand, Mr. Larson points out that design based on the NDT concept is uneconomical when the NDT exceeds the service-failure temperature by amounts from 60° F to 300° F as reported by Puzak, *et al.*

In replying to Mr. Puzak's discussion, the author would like to observe that no claims have been made that the 15-mil transition temperature does or, for that matter, should correlate with service-failure temperatures. To the contrary, the author contends that *no* laboratory brittle-fracture test can reproduce all of the variables associated with the design, fabrication and service environment of an engineering structure. Therefore, no attempt should be made to predict service performance from a laboratory brittle-fracture test unless a statistically reliable correlation has been established between the test in question and the particular service application. However, the relative notch sensitivity of different steels as influenced by various types of fabrication operations can be determined from laboratory brittle-fracture tests and, in turn, this information, tempered by engineering judgment and experience, may be used to estimate service performance.

In claiming that the NDT correlates directly with service and that all the service failures invesitgated were predictable from NDT considerations, Mr. Puzak is contending that the NDT is the highest temperature at which a brittle fracture can initiate in an engineering structure. This observation is not consistent with the NRL data[1] that are presented in Table C-1 for source-plate performance of ABS-A steel in ships. Since the Charpy V-notch energy absorption is less at the NDT (4 to 6 ft-lb) than at the service-failure temperature (5 to 8 ft-lb), the NDT must be somewhat lower than the service-failure tem-

Table C-1—Correlation of Crack Initiation with Charpy V-Notch Energy Values

	Crack-starter tests	NBS ship plate fractures
Avg.	4-6	5-8
Max.	8	11.4

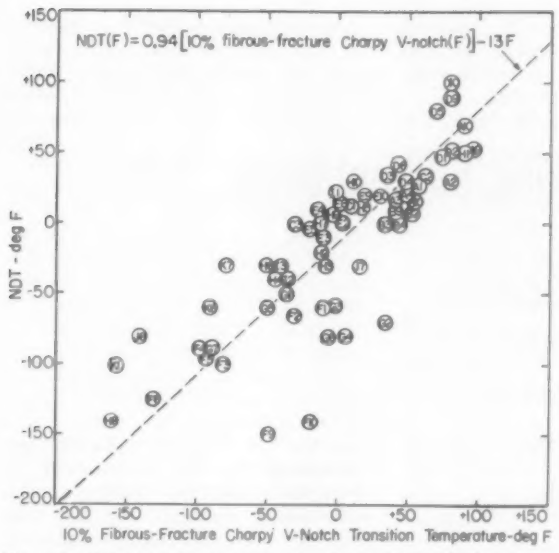
NDT(F)=0.94[10% fibrous-fracture Charpy V-notch(F)]-13F
NDT - deg F
10% Fibrous-Fracture Charpy V-Notch Transition Temperature-deg F

Fig. C-1—Relationship between the drop-weight NDT and the 10% fibrous-fracture Charpy V-notch transition temperature

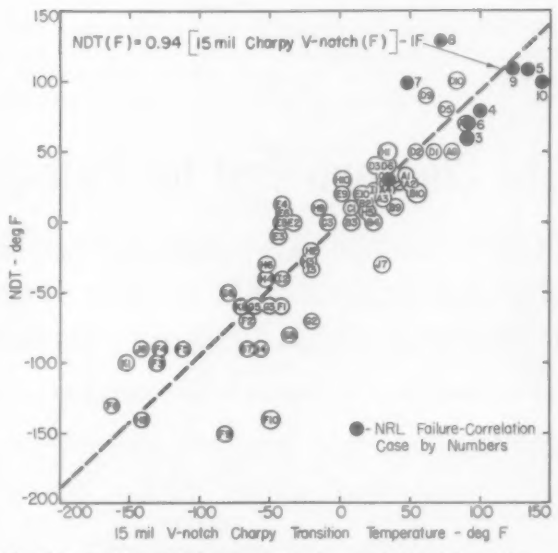
NDT(F)=0.94[15 mil Charpy V-notch(F)]-IF
NDT - deg F
15 mil V-notch Charpy Transition Temperature - deg F
- NRL Failure-Correlation Case by Numbers

Fig. C-2—Relationship between the drop-weight NDT and the 15-mil Charpy V-notch transition temperature for the NRL service-failure correlations

perature. Further, if the NDT of the plate and service-failure temperatures for these ships are assumed to be essentially the same, ship construction must represent the most severe conditions of notch sensitivity for ABS-A steel since no increase in the service-failure temperature would be possible if, as Mr. Puzak claims, the NDT is the highest temperature for crack initiation in any engineering structure.

The preceding observations suggest that the NDT may not always be a safe temperature for prevention of crack initiation in certain structures. However, the NRL data[2] also suggest that design based on the NDT may also be uneconomically conservative for other structures as pointed out by Mr. Larson. The author agrees with Mr. Larson on this point, but he does not concur with Mr. Larson's suggestion that many of the NDT values are considerably higher than the service-failure temperature because the NDT is related to crack propagation rather than crack initiation. The energy absorption at the NDT for ABS-A steel (Table C-1) corresponds to very small amounts of fibrous fracture. Furthermore, comparison of Fig. C-1 and Fig. 7 reveals that the NDT correlates better with the 10% fibrous-fracture Charpy V-notch transition temperature than with the 50% fibrous-fracture transition temperature. Thus the NDT appears to be more closely related to a crack-initiation criterion involving small amounts of fibrous-fracture than to a fracture-propagation criterion such as 50% fibrous-fracture. The author believes that variations between the NDT and the service-failure temperature are the result of different brittle-fracture susceptibilities for the different service structures that were investigated. On this basis, the NDT should not be considered as an absolute measure of service performance but rather as a relative test for service performance requiring a separate correlation for each service application. This approach, although restrictive, places the drop-weight test in the same category with other laboratory brittle-fracture tests.

Mr. Puzak has also shown that, for Case 7 and 8,[2] the NDT and the 15-mil transition temperature are in poor agreement. It should be noted that for all the other cases the agreement is reasonably good, as shown in Fig. C-2. However, the author agrees with Mr. Puzak's observation that the scatter is too great to permit prediction, at present, of the NDT from the 15-mil transition temperature. It was an analysis of the probable causes of scatter that resulted in the conclusion that anomalous drop-weight behavior was the principal cause for the scatter. The author is firmly convinced that drop-weight test behavior may be influenced by the heat-affected zone and, under these conditions, the drop-weight test does not assess the brittle-fracture susceptibility of the base material. Therefore, the 15-mil transition temperature for the base plate would not be expected to agree with the NDT. However, the data strongly suggest that the 15-mil transition temperature can predict the NDT with reasonable accuracy, providing the NDT represents the behavior of the base plate and is not complicated by heat-affected-zone influences.

In closing, the author would like to observe that neither the paper nor the closure are intended to question the usefulness of the drop-weight test. On the contrary, results from drop-weight testing have been responsible for a better understanding of the variation in the notch toughness of different types of steel. For example, studies based on drop-weight testing have shown that a greater energy absorption is required for alloy steels than for carbon steels to insure the same resistance to brittle fracture. However, the author is of the opinion that the drop-weight test is being applied too broadly when attempts are made to predict service performance for all types of structures under a variety of operating conditions. Service performance from a laboratory test can be predicted only for a particular service application through direct correlation with failure, and the information obtained from one correlation can be applied to a different service application only by means of good engineering judgment.

References

1. Puzak, P. P., Eschbacher, E. W. and Pellini, W. S. "Initiation and Propagation of Brittle Fracture in Structural Steel," THE WELDING JOURNAL, **31** (12), Research Suppl., 561-s to 581-s (1952).

2. Puzak, P. P., Babecki, A. J. and Pellini, W. S., "Correlations of Brittle-Fracture Service Failures with Laboratory Notch-Ductility Tests," *Ibid.*, **37** (9), Research Suppl., 391-s to 410-s (1958).

The Cruciform Test for Plate-Cracking Susceptibility

Object of investigation is to determine the effect of selected test conditions on the ability of the cruciform test to differentiate between a good and a bad heat of armor

BY LAURENCE E. POTEAT AND WILLIAM L. WARNER

The M-59 armored personnel carrier. A typical application of $^3/_8$-in.-thick armor plate

ABSTRACT. An investigation of the cruciform test was made to determine the effect of different test conditions on the ability of the test to separate a crack-susceptible heat of armor steel from a non-crack-susceptible heat. Conditions investigated were specimen fit-up, specimen temperature (preheat and interpass) and specimen size. Results indicate that the test is more sensitive to testing conditions (temperature, fit-up, plate size, etc.) than it is to differences in degree of crack susceptibility of the base metal used.

Introduction

Background

In 1953 the Research Group of the Ordnance Advisory Committee[1] on the Welding of Armor devised a detailed procedure for an armor-plate crack-sensitivity test. The procedure was based on previous work with the double-T specimen which had been used by Herres and Woodward[2, 3] at Watertown Arsenal in an investigation of structural steels and electrodes, and for the evaluation of hydrogen cracking.

The object of the cruciform test, as stated by the Committee, was to differentiate between various heats of armor steel as to susceptibility to heat-affected zone cracking associated with the making of fillet welds. This type of cracking has been a frequent difficulty encountered in the fabrication of armored vehicles. Because the Committee realized that the test had not been completely evaluated for this purpose, they advised the Ordnance Corps to determine the potential worth of the test for evaluating the crack sensitivity of armor plate. They also requested that armor fabricators using the test in their own plant should make available to the Committee any data obtained.

The cruciform specimen as proposed by the Ordnance Advisory Committee consists of three 12-in. long steel plates joined together to form a 90-deg cross with four 6-in. legs as shown in Fig. 1. The small plates are tack welded to the large plate at the ends to assemble the specimen for welding. To test for crack susceptibility, four fillet welds, each 6 in. long, are deposited in sequence between the legs of the specimen. The first fillet weld produces high restraint in the specimen; and as each successive weld is made, a higher degree of restraint is developed. Cracking of the specimen is supposed to

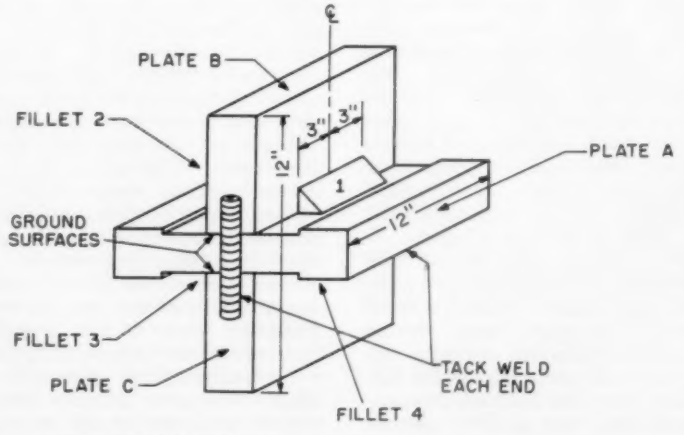

Fig. 1—The cruciform-test specimen

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The opinions herein expressed are those of the authors and do not necessarily represent those of the Ordnance Corps.

indicate a crack-susceptible material. Complete details of the cruciform-test procedure, as proposed by the Ordnance Advisory Committee, are given in the Appendix.

The cruciform test procedure, as approved, has been used by several investigators. W. G. Smith[4] used the test to evaluate the relative weldability of heats with and without rare earth additions. Of the three heats investigated, all cracked in the cruciform test. Although there was a difference in the amount of cracking among the three heats tested, the difference was slight and not regarded as significant. An investigation was made by Weiss, Ramsey and Udin[5] to compare and evaluate three different crack-susceptibility tests. They found that although the cooling rate was essentially the same for the cruciform test, the British controlled-thermal severity (CTS) test, and the multiple bead-on-plate test, only the cruciform test produced cracking in the steels investigated. Moreover, with cooling rates six times normal in the CTS test, there was still no cracking. Thus restraint—not thermal severity—was concluded to be the controlling factor in underbead cracking. Among the materials used in this investigation were two of the same heats previously used by Smith.[4]

A preliminary investigation of the cruciform test using heats of known production history was made by B. A. Schevo[6] at Detroit Arsenal. From the results of these investigations, the following observations appear to be justified: (1) for all conditions investigated, cracking was most frequent under the third weld, next most frequent under the first and least frequent under the second weld; (2) fillet sizes of $^3/_{16}$, $^1/_4$, $^5/_{16}$, $^3/_8$ and $^5/_8$ in. all produced cracking in both good and bad heats; and (3) the lower strength Grade 80 electrode gave the same results (with a single exception) as the higher strength Grade 230 electrode. Thus, from this preliminary work at Detroit Arsenal, it appears that neither fillet size nor strength of electrode are, of themselves, critical factors.

Scope of the Investigation

The investigation at Watertown Arsenal Laboratories was limited to the evaluation of three test conditions for the cruciform test; viz., fit-up, specimen temperature and specimen size. The material used was limited to two heats of standard manganese-molybdenum steel armor of known production history. Except for the test conditions under investigation, the procedures approved by the Ordnance Advisory Committee was followed exactly.

Object of the Investigation

The object was to determine the effect of selected test conditions on the ability of the cruciform test to differentiate between a good and a bad heat of armor.

Materials

Electrode

In this investigation only one type of electrode, Grade 230 (E-10016), low hydrogen, was used. All electrodes were from the same heat of wire and same batch of coating. All were $^3/_{16}$-in. diam and were dried at 250° F for at least 12 hr prior to use.

Selection of Armor Heats

Five-eighths-inch-thick standard Army Ordnance manganese-molybdenum armor plate made to Army Specifications MIL-A-12560 was used in this investigation. This type of armor has a tensile strength of approximately 180,000 psi and a hardness of 340 to 380 Bhn.

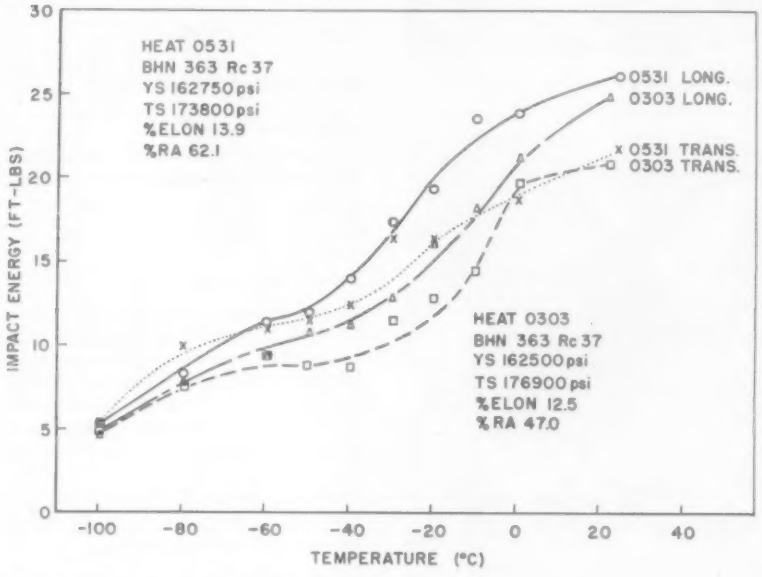
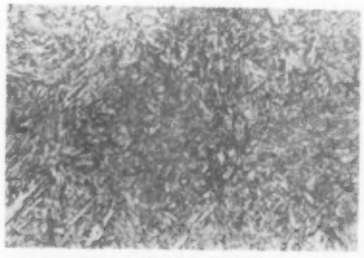
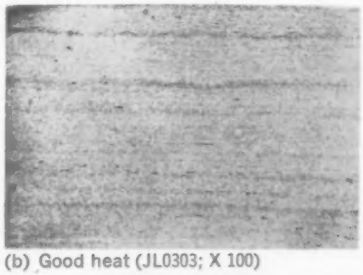


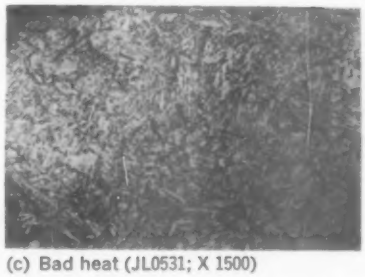
Fig. 2—Charpy and tensile results for armor heats



(a) Good heat (JL0303; X 1500)



(b) Good heat (JL0303; X 100)



(c) Bad heat (JL0531; X 1500)

(d) Bad heat (JL0531; X 100)

Fig. 3—Microstructure of good and bad heats of armor. (Reduced by $^2/_3$ upon reproduction)

Table 1—Chemical Analysis, %, of JL0531 and JL0303 Heats

Heat	C	Mn	Si	S	P	Ni	Cr	Mo	V
JL0531	0.28	1.65	0.14	0.015	0.014	Trace	0.03	0.53	Tr
JL0303	0.27	1.87	0.19	0.014	0.019	Trace	0.02	0.50	Tr

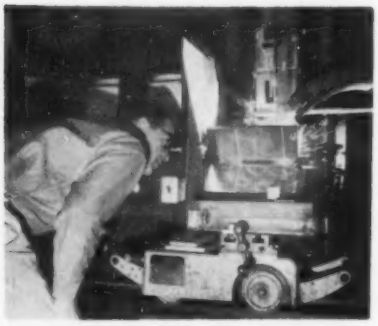


Fig. 4—Welding a cruciform specimen

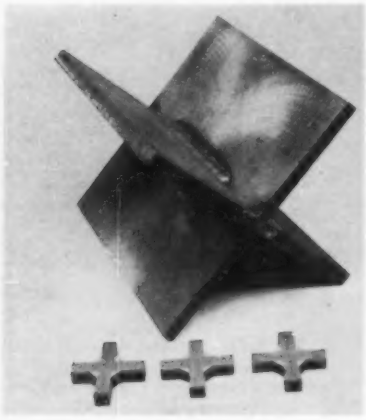


Fig. 5—The completed cruciform specimen showing cross sections

It was desired to use two heats with similar properties except for their susceptibility to weld cracking during fabrication. Based upon information obtained from Detroit Arsenal, the two heats selected for investigation were JL 0303 and JL 0531. Detroit Arsenal[7] reported heat JL 0303 to be "weldable, with good fabrication history" and heat JL 0531 to be "difficult to weld due to fillet-toe cracking." Later information from another source[8] stated that out of 152 plates of heat JL 0531 which were used in production, 66% of the plates showed cracking. The firm had no record of fabrication difficulties with heat JL 0303.

These two heats were concurrently under investigation at Watertown Arsenal Laboratories using the circular-patch test,[9] which indicated heat JL 0531 to be much more susceptible to cracking than heat JL 0303.

The chemical analysis of the two heats is given in Table 1.

Tensile strengths and Charpy transition curves of the two heats are shown in Fig. 2. An examination of the microstructures revealed no noticeable difference between heat JL 0303 and heat JL 0531. Typical microstructures are shown in Fig. 3. On the basis of this information, the two heats were assumed to be similar in all respects except for crack susceptibility.

Experimental Procedure

Welding Procedure

The following weld conditions were used throughout the investigation:

Current, amp.....210–220
Voltage, v.....19–20
Travel speed, ipm.....5

Travel speeds were checked prior to each test, and voltage and current were recorded on automatic recording meters. These conditions produced a $^{5}/_{16}$-in. fillet held within $\pm^{1}/_{32}$ in. The arc was ignited by a small ball of steel wool between the electrode and the specimen. The crater at the end of the weld was filled by stopping the travel before the arc was extinguished.

Welding Equipment

All welds were made using direct current, reverse polarity, from a 600-amp motor generator. Current was held constant within 1% for all tests. Arc travel was obtained by mounting the specimen on a standard welding carriage. Travel speed was controlled by an electronic-control unit and kept constant at 5 in. $\pm$ $^{1}/_{8}$ in. per minute for all welds in the investigation.

A special stick-electrode welding machine built by Massachusetts Institute of Technology for a previous investigation[5] was used throughout the study. This machine automatically fed a standard manual electrode and acted as a welding-voltage control, which held voltage constant during the test to within 1 v of the desired value. Complete details of the automatic stick-feeder mechanism are given in the Appendix of Reference 5.

Special precautions were taken to eliminate any chance of arc blow during welding. A special ground clamp was placed on the end of the specimen, and the direction of welding was away from the ground. Blocks of steel were placed at each end of the weld, and a short arc length was used. With these precautions, no noticeable arc blow or magnetic disturbance was encountered.

Figure 4 shows the operator welding a cruciform specimen. Electric controls are on the panel to the left with the recording meters, and the electrode-feed motor is mounted behind the rubber drive wheel and electrode holder. Note the travel carriage and the special ground clamp.

Test Procedure

Three series of tests were made in duplicate using the two selected heats. Test conditions followed the approved procedure except for the conditions being varied. These conditions were (1) specimen fit-up, (2) specimen temperature and (3) specimen size. The extent of cracking in the specimen was revealed by hot etching and microexamination of the weld cross section.

In the first series of tests, the effect of variations in the fit-up of the abutting surfaces was investigated. These surfaces, i.e., one edge of each small plate and the top and bottom surfaces of the larger plate, were prepared by four different methods before assembling. The smoothest surface was obtained by surface grinding; this produced a surface of 10 microinches rms as measured by profilometer. Blanchard grinding produced a surface of approximately 20 rms, and shaper machining produced a surface of 32 to 63 rms. The fourth method was by flame cutting. Five conditions of joint fit-up were investigated: (1) surface ground to surface ground, (2) Blanchard ground to Blanchard ground, (3) shaper machined to Blanchard ground, (4) oxygen cut to wire brushed and (5) oxygen cut to wire brushed, with $^{1}/_{16}$-in. spacers, to provide a controlled root gap between surfaces. Other conditions were as recommended; i.e., standard specimen with 80° preheat and interpass, etc.

The second series of tests was made varying the preheat and interpass temperature. The temperature of the specimen was determined by a hand pyrometer prior to the start of each weld. For each specimen the temperature was held the same for all four welds within ±5° F. Three test temperatures were used: 80, 165 and 250° F. For the 165 and 250 tests,

preheat was obtained by furnace heating the specimen 50° F higher than the test temperature and starting the test when the specimen had cooled to the correct temperature. The contact surfaces of the plates were Blanchard ground prior to assembly for this series.

The final series of tests was made to evaluate the effect of varying the size of the specimen. The over-all length of the specimen was kept at 12 in. while the width was varied between 4 and 12 in. This series was limited to one heat (JL 0303) due to lack of material. Other conditions were as recommended; i.e., 20 rms surface (Blanchard ground), 80° F preheat and interpass temperature, etc.

Evaluation Procedure

Each specimen was allowed to age at room temperature for 48 hr after completion of welding. After aging, the specimens were stress relieved to reduce the chance of cracking or crack propagation during sectioning. To stress relieve, each specimen was heated to 1150° F at a rate of 100° F per hour; after holding at 1150° F for 2 hr, the specimen was cooled at 100° F per hour to below 300° F and removed from the furnace to air cool (procedure recommended by the Ordnance Advisory Committee).

After stress relieving, a part of each leg was removed by oxygen cutting to reduce the size of specimen. Six $^1/_2$-in.-thick cross sections were machine cut from the center section of each specimen; one surface of each cross section was then polished on a fine belt sander. A hot etch was used to reveal cracking in the specimen (solution of 38% HCl, 12% H_2SO_4 and 50% H_2O at 170° F for 5 min.) Examination for cracks was made by binocular microscope at 30 magnification. The finished welded test specimen and reduced cross sections are illustrated in Fig. 5.

The recommended procedure for the cruciform test called for an evaluation on a "go or no-go" basis; i.e., on whether cracks did or did not occur. However, in most of the tests, cracking occurred in both the good and bad heats of steel, thus, such a criterion offered no positive basis for comparison. In the evaluation of crack susceptibility tests at M.I.T.[5], the investigators came to the same conclusion and recommended that a quantitative measure of the extent of cracking was a necessary criterion of crack susceptibility in the

Table 2—Results

Test No.	Test variable	Heat	Cracks in units of $^1/_{64}$ in. — Leg 1	Leg 2	Leg 3	Leg 4	Total	Cracking, %
	Contact surface							
18	Surface ground edge to surface ground surface	Good	0	0	100	0	100	21
19	Surface ground edge to surface ground surface	Good	0	0	68	0	68	14
10	Surface ground edge to surface ground surface	Bad	0	0	96	0	96	20
11	Surface ground edge to surface ground surface	Bad	4	0	120	0	124	26
21	Blanchard ground edge to Blanchard ground surface	Good	20	0	101	0	121	25
22	Blanchard ground edge to Blanchard ground surface	Good	18	0	96	0	114	24
3	Blanchard ground edge to Blanchard ground surface	Bad	56	0	84	0	140	29
20	Blanchard ground edge to Blanchard ground surface	Bad	66	0	94	0	160	33
16	Shaper machined edge to Blanchard ground surface	Good	0	0	98	0	98	20
17	Shaper machined edge to Blanchard ground surface	Good	0	0	90	0	90	19
8	Shaper machined edge to Blanchard ground surface	Bad	24	0	104	0	128	27
9	Shaper machined edge to Blanchard ground surface	Bad	50	8	86	0	144	30
12	Oxygen cut to wire brushed surface	Good	82	0	94	0	176	37
13	Oxygen cut to wire brushed surface	Good	0	0	94	0	94	20
4	Oxygen cut to wire brushed surface	Bad	0	0	120	120	240	50
5	Oxygen cut to wire brushed surface	Bad	0	0	120	4	124	26
14	Oxygen cut with $^1/_{16}$-in. spacer	Good	59	0	120	120	299	62
15	Oxygen cut with $^1/_{16}$-in. spacer	Good	118	0	120	22	260	54
6	Oxygen cut with $^1/_{16}$-in. spacer	Bad	8	0	120	38	166	35
7	Oxygen cut with $^1/_{16}$-in. spacer	Bad	78	0	120	120	318	66
	Preheat and interpass temperature							
21	80° F	Good	20	0	101	0	121	25
22	80° F	Good	18	0	96	0	114	24
3	80° F	Bad	56	0	84	0	140	29
20	80° F	Bad	66	0	94	0	160	33
35	165° F	Good	0	0	38	0	38	7.9
37	165° F	Good	0	0	11	0	11	2.3
34	165° F	Bad	0	0	8	0	8	1.7
36	165° F	Bad	0	0	6	0	6	1.3
23	250° F	Good	0	0	0	0	0	0
24	250° F	Good	0	0	0	0	0	0
25	250° F	Bad	0	0	0	0	0	0
	Size of test specimen							
21	12 x 12 x 12 in.	Good	20	0	101	0	121	25
22	12 x 12 x 12 in.	Good	18	0	96	0	114	24
26	8 x 8 x 12	Good	0	0	78	0	78	16
27	8 x 8 x 12	Good	0	0	80	0	80	17
28	6 x 6 x 12	Good	0	0	4	0	4	0.8
29	6 x 6 x 12	Good	0	0	0	0	0	0
30	4 x 4 x 12	Good	0	0	0	0	0	0
31	4 x 4 x 12	Good	0	0	0	0	0	0
32	4 x 4 x 12	Bad	0	0	0	0	0	0
33	4 x 4 x 12	Bad	0	0	0	0	0	0

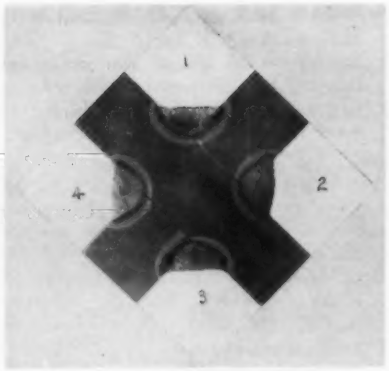


Fig. 6—Etched cross section of the cruciform specimen showing crack under first weld (top) and third weld (bottom)

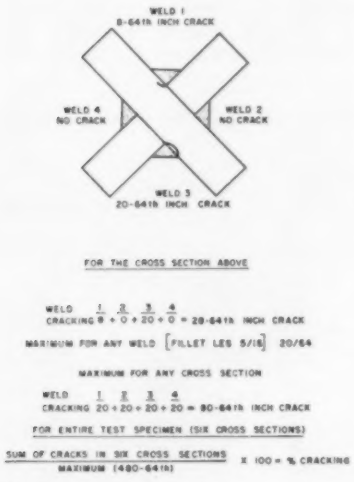

WELD 1
8-64ths INCH CRACK
WELD 4
NO CRACK
WELD 2
NO CRACK
WELD 3
20-64th INCH CRACK
FOR THE CROSS SECTION ABOVE
WELD 1 2 3 4
CRACKING 8 + 0 + 20 + 0 = 28-64th INCH CRACK
MAXIMUM FOR ANY WELD [FILLET LEG 5/16] 20/64
MAXIMUM FOR ANY CROSS SECTION
WELD 1 2 3 4
CRACKING 20 + 20 + 20 + 20 = 80-64th INCH CRACK
FOR ENTIRE TEST SPECIMEN (SIX CROSS SECTIONS)
SUM OF CRACKS IN SIX CROSS SECTIONS / MAXIMUM (480-64th) X 100 = % CRACKING

Fig. 7—Measurement of specimen cracking

cruciform test. The extent of cracking was measured by an approximate calculation of the surface area exposed by each crack. The size of the crack was measured as the width of cracking in each cross section; as each cross section was $^1/_2$ in. thick, the approximate length of the crack was indicated by the number of sections in which the crack appeared. To simplify the procedure, the width of crack in each cross section was measured in units of $^1/_{64}$ in. at a magnification of × 30 under a binocular microscope. The sum of these units for a crack in the six cross sections was an indication of the surface area exposed by each crack.

The sum of the total number of observed cracks (in units of $^1/_{64}$ in.) divided by the maximum amount of cracking possible (all four welds completely cracked) was taken as the percent cracking in the test specimen. This percentage was used in comparing the different specimens.

A typical etched cross section of a specimen as examined is shown in Fig. 6. An example of the measurement and determination of cracking percentage is shown in Fig. 7.

Results and Discussion

The results of this investigation are shown in Table 2.

Similar trends were obtained by both this investigation and the Detroit Arsenal investigation. In all tests which followed the approved procedure, cracking was observed with both good and bad heats. In both investigations, the most frequent cracking was observed under the third weld. The third weld appears to be the most vulnerable to cracking due to the conditions set up by the first two welds. The leg attached by the first two welds increases the rigidity of the specimen, thus producing more severe conditions for the third and fourth welds. It is thought that the third weld cracks when the fourth weld is being made due to the specimen being too rigid to allow the necessary movement. In the same way, the first weld cracks when the second weld is made, but to a lesser extent than the third weld. Cracking was observed under the fourth weld only under the most severe conditions.

Specimen Fit-up

Specimen cracking varied with changes in the condition of the contacting surfaces. The least cracking was found in the surface-ground specimen and the most severe cracking was found in the oxygen-cut specimen. Average values for cracking as obtained from duplicate specimens for each test condition are given in Table 3.

Surface preparation, if machined or ground, made only a small difference in the cracking. The most severe cracks were observed when a $^1/_{16}$-in. root gap was used with the oxygen-cut edge. There was no condition found in which the bad heat cracked and the good heat did not crack, which would allow a "go no-go" type of evaluation.

Table 3—Average Cracking Values

Surface preparation	Average cracking, % Good heat	Bad heat
Surface ground	18	23
Blanchard ground	25	31
Machined edge to ground plate	20	29
Flame-cut edge to wire-brushed surface	29	38
As above but with $^1/_{16}$-in. root gap	58	51

If thermal severity is the controlling factor in underbead cracking, the specimen with the $^1/_{16}$-in. root gap would be expected to show the least cracking as the gap would reduce the rate of cooling. The opposite trend in cracking was observed which substantiates the conclusion of Weiss *et al.*[5], that restraint is a more important factor than thermal severity. Oxygen-cutting heat effects were not a contributing factor as most of the cracking occurred in the 12- x 12-in. plates.

Specimen Temperature

A marked decrease in cracking was observed with increasing specimen temperature. Both good and bad heats showed decreasing cracking as the temperature was raised, as shown in Table 4.

Table 4—Cracking Tendency vs. Specimen Temperature

Preheat and interpass temperature, ° F	Average cracking, % Good heat	Bad heat
Room temperature (80° F)	25	31
165	5	2
250	0	0

Size of Test Specimen

Cracking tendency decreased with size of test specimen (see Table 5).

Table 5—Cracking Tendency vs. Specimen Size

Size (in.)	Average Cracking, % (Good Heat)
12 x 12 x 12	25
12 x 8 x 8	17
12 x 6 x 6	$^1/_2$
12 x 4 x 4	0

Consistency of Test Results

To determine the reproducibility of the cruciform test, a comparison was made of the results of a series of six similar test conditions, made in duplicate. These tests—the first twelve in Table 2—differ only in method of surface preparation and heat of armor. The average difference for duplicate tests was 3.6% cracking with a range of difference of 1 to 7%. The results from the other specimens in the investigation were equally consistent for duplicate tests, with the exception of those in which the specimen edges were oxygen cut.

Difference in Good and Bad Heats

From the same series of 12 tests, the good heat showed an average cracking of 20.5%, and the bad heat showed 27.5% cracking. The bad heat showed more cracking than the good heat in all tests of the investigation, except in the tests involving oxygen-cut edges and a $^1/_{16}$-in. root gap (the differences indicated by the tests with the 165° F preheat and interpass temperature are small and may not be significant).

Summary and Conclusions

In this investigation, made under optimum laboratory conditions, the cruciform test for crack susceptibility indicated only a slight difference between a good and a bad heat of armor. The variation in duplicate tests was almost as great as the variation between good and bad heats. From the results of this study, it can be concluded that, under test conditions in a production shop, the cruciform test in its present state of development appears unsuitable as a crack-susceptibility test for armor steel.

Recommendations for Future Work

This investigation was limited to preliminary experiments on two heats of armor steel. While the data indicate that the cruciform test, as it now exists, is not satisfactory, additional experiments are necessary before a complete evaluation can be made. Therefore, it is recommended that the following factors be investigated using a number of different heats of armor of known fabrication history:

1. Restraint as achieved through specimen-size variation.
2. Cooling rate as controlled by specimen temperature.
3. Both restraint and cooling rate as effected by fillet size.
4. Mechanism and sequence of cracking to determine whether hot or cold cracking occurs.

Further information on these should determine if the cruciform test can be used or if it should be discarded as an armor crack-susceptibility test.

References

1. Minutes of the Ordnance Advisory Committee on Welding of Armor Research Group, Oct. 6–7, 1953, Pentagon Building, Washington, D. C.
2. Herres, S. A., and Woodward, P. E., "Welding of High-Strength Constructional Steels with Ferritic Electrode," THE WELDING JOURNAL, 25 (10), Research Suppl., 646-s to 658-s (1946).
3. Herres, S. A., "Practical Importance of Hydrogen in Metal-Arc Welding of Steel," *Trans. ASM*, 39, 162 (1947).
4. Smith, W. G., "Weldability of Rare Earth Treated Homogeneous Armor Steel Plate," Interim Rept. No. 1, WAL File No. 642/218-1, Contract No. DA-36-034-ORD-1423RD, Feb. 14, 1955.
5. Weiss, S., Ramsey, J. M., and Udin, H., "Evaluation of Weld-Cracking Tests on Armor Steel," THE WELDING JOURNAL, 35 (7), Research Suppl., 348-s to 356-s (1956); also WAL Rept. No. 640/222, September 1955.
6. Presented at OMRO Meeting on "Tests for Evaluation of Welding Procedure and Materials," Watertown Arsenal, Feb. 25–26, 1958.
7. Detroit Arsenal Letter dated Oct. 4, 1957.
8. International Harvester Letter dated Feb. 18, 1958.
9. Potest, L. E., and Jones, R. W., "Circular Patch Test for Evaluating Armor Crack-Susceptibility," WAL Rept. No. 710/1075.

APPENDIX

Test Procedure for Cruciform Test* (Cruciform or Double-T)

Material

Plate Type and Thickness. The plate material will be armor plate accepted under Ordnance armor specifications. Data on base metal required for any test program using this test procedure shall be: specification number, steel heat number, lot and plate number—if any, manufacturer and plate chemistry, plate thickness.

The form of test specimen to be used is shown by Fig. A-1.

For a complete test of a specific heat of steel the tests shall be made with plate in three thicknesses—$^1/_2$, 1 and $1^1/_2$ in. However, tests of other plate thicknesses are acceptable in those instances where either one or all of the prescribed thicknesses are not available or the tester desires to test a particular thickness.

Plate Sizes. (*a*) $^1/_2$*-In. Plate Thickness:* one plate (A), 12 x 12 x $^1/_2$ in.; two plates (B and C), 6 x 12 x $^1/_2$ in.

(*b*) *1-In. Plate Thickness:* One plate (A), 8 x 12 x 1 in.; two plates (B and C), 4 x 12 x 1 in.

(*c*) $1^1/_2$*-In. Plate Thickness:* One plate (A), 8 x 12 x $1^1/_2$ in.; two plates (B and C), 4 x 12 x $1^1/_2$ in.

Plate Preparation (*see Fig. A-1.* (*a*) *Plate A:* Grind a strip across both faces to a smooth surface of maximum 20 rms so that these strips are opposite each other. The minimum width of each strip (dimension W) shall be: $^1/_2$-in. plate 3 in.; 1-in. plate, 4 in.; $1^1/_2$-in. plate, 5 in. The minimum plate thickness between strips (dimension *t*) shall not be less than $^1/_2$-in. plate A, 0.430 in.; 1-in. plate A, 0.920 in.; $1^1/_2$-in. plate A, 1.410 in.

(*b*) *Plates B and C:* Grind one 12-in. edge of each plate to a smooth surface of maximum 20 rms so that this edge surface is approximately at right angles to the plate surface.

* Taken from Minutes of the Ordnance Advisory Committee on Welding of Armor Research Group, Oct. 6–7, 1953, Pentagon Building, Washington, D. C.

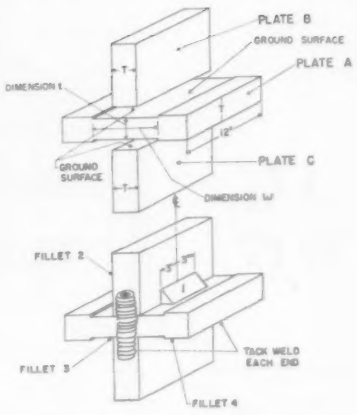


Fig. A-1—The cruciform (or double-T) specimen

Assembly of the Test Specimen (see Fig. A-1)

Plate Examination. Prior to assembly of the test specimen examine all plates for cracks or laminations, particularly the ground surfaces, by a magnetic penetrant dye-check particle method. After this examination, the plates which are to be used for the test specimen shall be demagnetized.

Assembly and Tacking. Assemble the test specimen as shown in Fig. A-1 with the ground edges of Plates B and C in intimate contact with the ground strips of Plate A. Clamp plates securely and tack weld as shown by Fig. A-1. After tack welding is completed, remove clamps.

Welding of the Test Specimen

Electrode. The fillet welds shown by Fig. A-1 and A-2 shall be made with an electrode approved as Grade 230 under specification MIL-E-986. If, during the progress of welding a test specimen, cracking of the weld metal occurs, the result shall be regarded as no test. Care shall be exercised that the electrodes used for the test are from a freshly opened container, and dry.

Welding Current. Welding of test specimens shall be performed with direct current, reverse polarity (electrode positive). This is not taken to prohibit the use of either direct current, straight polarity or alternating current for spot checking as the tester may desire.

Sequence of Welding (see Figs. A-1 and A-2). (*a*) *Fillet Welds* (*Nos. 1–4*): Each fillet weld shall be 6 in. long and so placed as to extend 3 in. on each side of the midpoint of the length of the test specimen (see Fig. A-1).

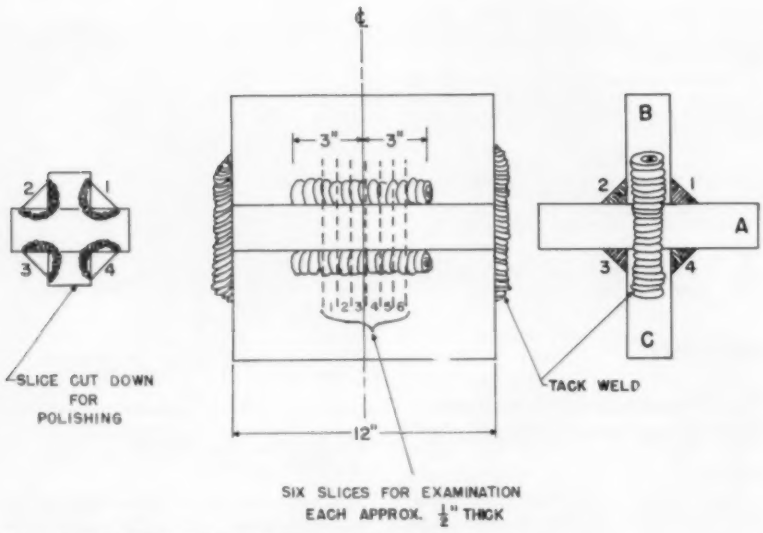


Fig. A-2—Examination of cruciform (or double-T) specimen

(*b*) *Deposition:* Each fillet weld shall be deposited in the flat or downhand position and in the sequence as indicated by Figs. A-1 and A-2. The four fillet welds shall all be deposited with the same relative direction of arc travel, each fillet being deposited by a single pass of the welding arc without any arc interruption.

(*c*) *Craters:* The craters at the ends of the fillet welds shall be filled prior to extinguishing the welding arc in each case. Care shall be exercised that limiting plate temperature is not exceeded when starting to deposit any of the fillet welds (see Plate Temperature).

(*d*) *Fillet Identification*: Each fillet weld of the test specimen shall be so marked that the order of deposition of the fillet welds is indicated.

Plate Temperature. In no instance when starting to deposit any of the fillet welds shall the temperature of the base metal be other than 80 ± 5° F. This plate temperature shall be determined at the location of the start of welding in each case.

Size of Welds. (*a*) *Energy Input:* Only one size of fillet weld shall be used per test specimen (Fig. A-1). For each plate thickness to be tested, several fillet-weld sizes shall be used such that the weld heat input is varied to bracket, if possible, the critical conditions which produce base-metal cracking. The size of fillet welds on each test specimen must be closely held (accurately measured within ± 1/32 in.). Fillet welds shall be deposited by machine welding.

(*b*) *Welding Data:* All information necessary for calculation of heat input in Joules per inch of weld shall be recorded. These data include: Welding current in amperes; arc voltage at the electrode nozzle; arc time per fillet weld, or speed of arc travel; electrode size and length (in inches) of electrode consumed per fillet weld.

Examination of the Test Specimen

Aging Period. Following completion of the welding, the test specimen shall be allowed to stand at least 48 hr at room temperature (not less than 65° F) before sectioning.

Stress Relieving. Following the aging period and prior to sectioning, the test specimen shall be stress relieved in a suitable furnace at a temperature of 1100–1200° F for a minimum of 2 hr, and furnace cooled. Test specimens shall not be inserted into the furnace when the furnace temperature is in excess of 300° F. The rate of heating of the test specimen above 300° F shall not exceed 100° F per hour. The rate of cooling of the test specimen after the 2-hr hold shall not exceed 100° F per hour. The test specimen may be removed from the furnace during cooling when the furnace temperature has been reduced to approximately 300° F.

Sectioning. (*a*) *Number of Slices:* Following stress relieving, the test specimen shall be sectioned as indicated by Fig. A-2. At least six slices shall be taken, each slice approximately 1/2 in. thick.

(*b*) *Location:* No cross section of the test specimen shall be taken for examination within 1 in. of either end of any fillet weld.

(*c*) *Cutting Slices:* Sectioning shall be done by mechanical cutting and care shall be exercised to prevent "wandering" of the cutter. Care shall also be exercised to avoid heating the slices during cutting.

(*d*) *Identification of Slices:* Each slice shall be identified so that its respective location in the test specimen with reference to the other five slices may be clearly recognized. Each fillet-weld cross section in each slice shall also be identified so that its relative deposition sequence with reference to the other three fillet welds may be clearly understood.

Preparation of Slices. One face of each slice shall be surface ground and polished for microexamination. (Polishing with a 2 zero paper is recommended.) The face of each slice which is polished shall be that toward the crater end of the fillet welds. For the purpose of grinding and polishing, the size of the slice may be reduced to that which will just encompass the four welds with their heat-affected zones as shown by Fig. A-2.

Etching of Slices. The polished surface of each slice shall be etched by the following procedure:

Etching solution: 10% sulfuric acid, 90% water
Etching temperature: 180° F
Etching time: 3 to 5 min in solution

The polished specimen shall be immersed in the etching solution which is at a temperature of 180° F and so maintained during the period of immersion of the specimen (3 to 5 min).

Following the hot etch, the specimen shall be removed from the etching solution and rinsed in water to remove all traces of acid, and thoroughly dried as quickly as possible to prevent staining of the etched surface.

Examination of Slices. The etched surface of each slice shall be examined for evidence of cracking in weld or heat-affected zone of each fillet weld. This examination shall be performed by binocular microscope at a minimum magnification of 30 diam. Findings shall be recorded with reference to weld number and plate letter for each specimen slice examined.

Data to Be Recorded per Weld-test Specimen

The following data shall be recorded for each weld-test specimen (Fig. A-1): Base metal data (A1); welding data (C5b); Slice number and weld number (Fig. A-2). Indicate presence of absence of cracks and whether in weld metal or base metal, if present. Plate letter shall be used to indicate location of base-metal cracks.

Factors Affecting Severity of Cruciform Test for Hardened-Zone Cracking

Investigation indicates that higher effective hydrogen level, higher cooling rates and higher contraction stresses are among the contributing factors

BY K. WINTERTON AND M. J. NOLAN

ABSTRACT. It has been shown, using a particular combination of metal-arc electrode and alloy-steel plate, that the cruciform test is a more severe test for hardened-zone cracking than the controlled-thermal-severity test.

Various modifications of the cruciform test have been tried, with the object of isolating the factors responsible for its greater severity. It has been found that hydrogen migration occurs between adjacent welds of the cruciform test, resulting in a higher effective hydrogen content. Apart from this factor, higher cooling rates and higher contraction stresses are also partly responsible for the severity of the test.

Introduction

Researches by Cottrell *et al.*,[1-5] appeared to have shown that the *incidence* of underbead cracking depended only on three factors—hydrogen level, cooling rate and steel composition. It was realized that the factor of restraint could be instrumental in extending fine cracks initiated by a suitable combination of the three controlling factors mentioned above.

This conclusion was based on the examination of a wide range of restrained fillets,[1] unrestrained fillets[2] and structural joints.[4] The studies led consequentially to the development of the controlled-thermal-severity (C.T.S.) test, which has been fully described elsewhere.[3, 5] This test has been used fairly widely since 1956 and has recently been the subject of some international weldability trials.[6]

Recently, an investigation by S. Weiss *et al.*,[7] showed that, under certain conditions, cracking could be obtained in the cruciform test, although it was not revealed under apparently parallel conditions in the C.T.S. test; the authors believed that these results were compatible with the assumption of higher "restraint" in the former test.

It was thought that it would be worth while to examine more closely the reasons for the greater severity of the cruciform test; first, because the explanation based on restraint did not seem adequate, and secondly, to explore the possibilities of hydrogen-migration effects.

Materials

The plate material used throughout was of the type NE8630X and its composition was as follows (in weight percent):

C	0.28
Mn	0.88
Ni	0.62
Cr	1.02
Mo	0.32

The $^{3}/_{16}$-in. diam low-hydrogen electrodes used for metal-arc welding were deposited at a welding current of 200 amp. These electrodes were of a particular brand conforming to AWS E7016 class, and were chosen because of the relatively high diffusible-hydrogen content characteristic of the deposited weld metal (approximately 5 cc/100 gm).

Some welds were also deposited using $^{1}/_{16}$-in. diam wire with the inert-gas metal-arc process, the welding current being approximately 255 amp. The wire used was supplied to the following composition (manufacturer's data):

C, max	0.10
Mn	1.25
Si	0.5
S, max	0.03
P, max	0.03
Ni	1.45
Cr, max	0.15
Mo	0.5
V	0.15

Test Procedure

Controlled-thermal-severity tests were carried out in accordance with the recommended procedures,[5] except that, for reasons that will become clear later on, the anchor welds were deposited by the inert-gas metal-arc process. The normal procedures include microscopical examination of three polished and etched sections from each of the test welds. The test assembly is shown in Fig. 1.

The cruciform tests were made initially in accordance with pro-

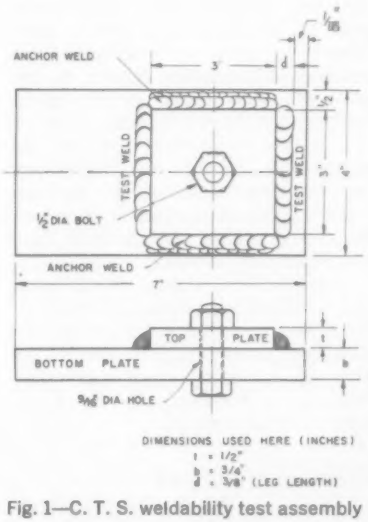


Fig. 1—C. T. S. weldability test assembly

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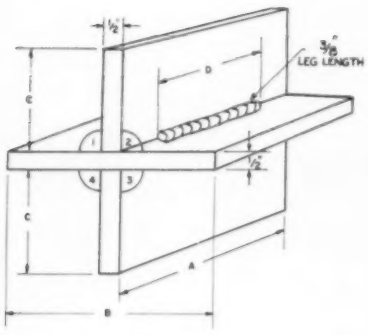

DIMENSIONS (INCHES)	A	B	C	D
TYPE 1	12	12	6	6
TYPE 2	6	6	3	6
TYPE 3	6	6	3	3

Fig. 2—Cruciform tests

cedures developed by the Research Group of the Ordnance Advisory Committee on Welding of Armor[9] (see Fig. 2; dimensions as for type 1). Later, however, to economize in plate material, a smaller version of the test was tried (Fig. 2; dimensions as for type 2). This was found to be equally effective from the point of view of producing cracks, so that it was adopted for all the later comparative testing described. It was afterwards found that a similar modification of the test had been used by Herres.[9, 10]

In the cruciform tests, an attempt was made to maintain a constant leg length of $^3/_8$ in. for all welds; for welds 6 in. in length, one complete electrode was consumed. The same leg length was used for welds deposited by the inert-gas metal-arc process.

The normal procedure adopted for the examination of test welds from the cruciform test, was to examine two sections cut at locations disposed symmetrically 1 in. apart and $^1/_2$ in. from the center line. These sections were ground and polished with emery papers to the 00 grade, and examined for cracks both visually and with the aid of the dry magnetic-powder method. In most cases, the cracks were obvious, but in cases of doubt, the sections were examined further in the polished and etched condition at high magnification (× 630).

Two determinations were made for diffusible-hydrogen content. This was done following procedures outlined elsewhere,[11] modified by the use of small steel specimens, held in a split copper block, as recently recommended.[12]

Experimental Work

The results for the cruciform tests

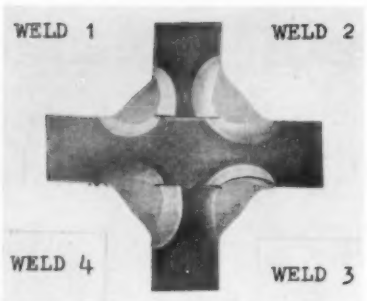

Fig. 3—Section from cracked cruciform assembly (Test 2)

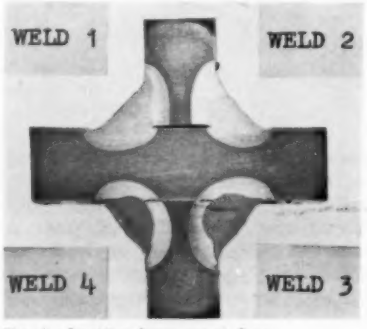

Fig. 4—Section from crack-free cruciform assembly (Test 6)

are given in Table 1.

It was established that, with the cruciform test, it is necessary to cool the assembly completely between welds to achieve greatest severity. This confirms a similar conclusion by Herres.[10] In a full-size test (test 1; Table 1), in which the four welds were deposited using low-hydrogen electrodes, without this intermediate cooling, no cracking was obtained.

However, a similar test, in which the assembly was permitted to cool to room temperature between passes, showed complete cracking in weld three and severe cracking in weld four (test 2). It would seem, therefore, that the higher cooling rate in this latter case is the dominant factor in initiating cracking.

The results of two tests (Nos. 3 and 4), made using a smaller size cruciform assembly, are included in Table 1, and it may be noted that again severe cracking was obtained. The procedure was then modified as follows. Welds one and two were deposited using the inert-gas metal-arc process, and welds three and four were made as before using the low-hydrogen test electrode (test 5). In this case, by contrast, no cracking was found, even by microscopical examination of polished and etched sections at high magnification (× 630); the result

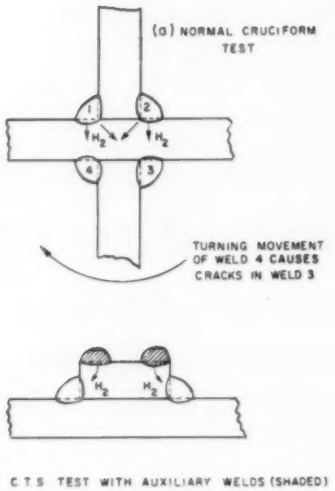

Fig. 5—Hydrogen-migration tests

was confirmed with a second test (test 6).

Figure 3 is a section from test 2, chosen because the cracking has in this case opened up perceptibly, so facilitating illustration. It is otherwise typical of the location and form of cracking that occurs in the cruciform test. Figure 4 is a section from test 6, where no cracking occurred. The welding speed and current for the inert-gas metal-arc process were adjusted so that the leg length of the resulting weld was $^3/_8$ in.; i.e., the same as that produced in the metal-arc welds. Since the configuration and, presumably, the restraint have been maintained constant, it must be assumed that cracking is normally obtained in welds three and four of the conventional cruciform test, partly because of hydrogen migration across the solid plate from welds one and two (Fig. 5a).

Measurements were made of the diffusible-hydrogen contents characteristic of the deposits produced by the low-hydrogen test electrode, and also by the inert-gas metal-arc process. It was found that 5.0 cc/100 gm were produced in the former case and a negligible amount in the latter. These values are consistent with the explanation offered above for the influence of welds one and two of the cruciform test.

In the cruciform test, general experience has shown that cracking is found most frequently, and is developed to a greater extent, in weld three. To account for this, Herres[10] has suggested that the embrittled hardened zone of this weld is cracked under the action of the turning movement supplied by weld four (see Fig. 5a). To examine

Table 1—Cruciform-test Results

Test no.	Type of test (see Fig. 2)	Remarks	Weld	Type	Hardness (DPN) Av Max[a]	Peak[b]	Cracking[c]
1	1	(without intermediate cooling between welds)	No. 1	E7016	...	...	None
			No. 2	E7016	...	...	None
			No. 3	E7016	...	...	None
			No. 4	E7016	...	...	None
2	1	(full-size test; with intermediate cooling)	No. 1	E7016	Vert 530	579	None
					Horiz. 585	585	
			No. 2	E7016	...	...	None
			No. 3	E7016	...	...	Complete
			No. 4	E7016	...	...	Severe
3	2	(modified test; with intermediate cooling)	No. 1	E7016	...	...	None
			No. 2	E7016	...	...	None
			No. 3	E7016	...	...	Complete
			No. 4	E7016	...	...	Severe
4	2	(same as test No. 3)	No. 1	E7016	Horiz. 535	549	None
			No. 2	E7016	...	...	None
			No. 3	E7016	Vert. 535	551	Severe
					Horiz. 565	594	
			No. 4	E7016	Vert. 574	609	Severe
					Horiz. 545	586	
5	2	(inert-gas metal arc for first two welds)	No. 1	IGMA[d]	...	...	None
			No. 2	IGMA	...	...	None
			No. 3	E7016	...	...	None
			No. 4	E7016	...	...	None
6	2	(same as test No. 5)	No. 1	IGMA	Vert. 520	530	None
					Horiz. 514	576	
			No. 2	IGMA	Vert. 561	579	
					Horiz. 541	600	None
			No. 3	E7016	...	...	None
			No. 4	E7016	...	...	None
7	2	(as test No. 5, but 4th weld omitted)	No. 1	E7016	...	...	None
			No. 2	E7016	...	...	None
			No. 3	E7016	...	...	None
			No. 4	No weld	...	...	...
8	2	(inert-gas metal arc for 2nd and 4th welds)	No. 1	E7016	...	...	None
			No. 2	IGMA	...	...	None
			No. 3	E7016	...	...	Severe
			No. 4	IGMA	...	...	None
9	3	(as test No. 5, but with short welds)	No. 1	E7016	Horiz. 549	600	None
			No. 2	E7016	...	...	Slight
			No. 3	E7016	Horiz. 555	622	Complete
			No. 4	E7016	...	...	Severe
10	2	(4-in. welds; lower vertical member omitted)	No. 1	E7016	...	...	None
			No. 2	IGMA	...	...	None
11	2	(as above, plus extra weld below test weld)	No. 1	E7016	...	...	Slight
			No. 2	IGMA	...	...	None
12	3	Before weld No. 3 baked 168 hr at 212° F	No. 1	E7016	...	...	None
			No. 2	E7016	...	...	None
			No. 3	E7016	...	...	Severe
			No. 4	E7016	...	...	Severe
13	2	Before weld No. 3 baked 168 hr at 212° F	No. 1	E7016	...	...	None
			No. 2	E7016	...	...	None
			No. 3	E7016	...	...	Severe
			No. 4	E7016	...	...	Moderate
14	2	Before weld No. 3 baked 40 hr at 600° F	No. 1	E7016	...	...	None
			No. 2	E7016	...	...	None
			No. 3	E7016	...	...	Moderate
			No. 4	E7016	...	...	None

[a] Average of highest hardness values adjacent to weld junction.
[b] Maximum single value.
[c] The remarks in this column refer to the distance crack extends from root to toe of the weld.
[d] Inert-gas metal arc.

this suggestion, a test was made in which the fourth weld was omitted (test 7). No cracking was found in weld three, even with microscopical examination of polished and etched sections at high magnification (× 630). Evidently, the fourth weld is required, under the test conditions, to initiate cracking in the third weld.

A test was also made in which the second and fourth welds were deposited using the inert-gas metal-arc process, to eliminate the factor of hydrogen migration from weld four to weld three (test 8). Weld three cracked under these conditions, which seems to show that the role of the fourth weld is to provide stress to initiate the cracking. Preliminary tests using a dial micrometer had shown that the rotation caused by a freely contracting weld deposited by the inert-gas metal-arc process was comparable with that produced by a manual metal-arc weld. In test 8, additional hydrogen could migrate to weld three only from weld one (diagonally opposite), instead of from both welds one and two as in the normal test.

Another modification of the cruciform test which has been tried, involves the use of welds 3 in. in length instead of the standard 6-in. length (Fig. 2; dimensions as for type 3). This resulted in some cracking in three of the four welds (test 9). This increased severity is associated with a somewhat increased cooling rate, particularly at the extremities of the welds. The hardness tests (Table 1) confirm that high cooling rates are obtained in this weld. Presumably this increased cooling rate is sufficient to cause slight cracking without additional hydrogen from adjacent welds.

Two inverted-Tee tests (tests 10 and 11) were then made, using the same configuration as for welds one and two of the cruciform test, but without the addition of the lower vertical member. The weld length was fixed at 4 in., on the assumption that this would provide a borderline condition for cracking. The second weld was deposited using the inert-gas metal-arc process, so that there was a possibility of cracking only in the case of the first weld. The two tests were identical, except that in one case an additional weld was laid on the horizontal plate, opposite the intended location of the test weld. Some cracking was obtained in the test weld when the additional weld was present, but not otherwise. This supports the idea that hydrogen migrating from neighboring welds can increase the cracking tendency.

An attempt was next made to see whether the hydrogen present in the first two welds could be eliminated by heat treatment, before laying welds three and four. Tests were made in which, after laying welds one and two, the assembly was treated for 168 hr at 212° F. (Compare test 12 with test 9, and test 13 with test 3 or 4 in Table 1.) Another assembly was treated for 40 hr at 600° F before laying the third and fourth welds (test 14). Reference to the results in Table 1 shows that, although the cracking was slightly reduced in severity, it was not entirely eliminated. However, it is not an easy matter to remove hydrogen completely from fairly massive samples. Tests by Flanigan,[13] on butt-welded plates, showed that a treatment of 168 hr at 250° C was only partially effective in removing hydrogen from the weld metal (from 4.1 cc/100 gm to about 2.3 cc/100 gm).

Probably treatment for longer duration at 600° F, or treatment at temperatures still higher than 600° F, would be effective in eliminating hydrogen from welds one and two of the cruciform test. It was decided, however, not to make further tests on these lines, since such treatments might introduce additional effects, such as the alleviation of residual stress.

It is worth noting that, in all cases where cracking occurred in the cruciform test, it occurred in the horizontal leg of the fillet, no doubt due to a somewhat greater cooling rate. Hardness tests appear to be consistent with this explanation.

Several attempts have been made with various modifications of the C.T.S. test to obtain cracking, in particular by the introduction of additional welds to provide the possibility of a hydrogen-migration effect. However, no cracking was found in any of these tests, even with microscopical examination of polished and etched sections at high magnification (× 630). A short account follows.

A controlled-thermal-severity test was made using the alloy steel for the top plate and thick mild steel for the bottom plate. The thickness of the latter (3/4 in.) was chosen so that in conjunction with the 1/2-in. top plate, the thermal severity would be approximately equivalent to that obtaining for weld three (and four) of the cruciform test (i.e., T.S.N. 8* in both tests). A similar test was made with the addition of an auxiliary weld, made before depositing the test weld, in the position shown in Fig. 5b.

Another controlled-thermal-severity test was made using the 1/2-in. alloy steel for both the top and bottom plates. The leg length was adjusted to 1/4 in.,† in order to maintain the thermal severity at the same level, and comparable with that of weld three of the cruciform test. The bottom plate was extended to a length of 10 in., to provide two equivalent test welds with trithermal severity. On the underside of the plate, an additional weld was provided opposite one of the test welds. However, no cracking was found in either of the test welds.

A few hardness tests have been made on the hardened zones of the test welds, mainly with a view to giving an indication of the relative cooling rates to which the zones had been subjected. These tests were made with a Tukon hardness testing machine, using a 500 gm load and a diamond pyramid indenter. The results are included in Table 1. For comparison, it may be noted that for one of the controlled-thermal-severity tests (first modification; vertical leg), the values obtained were 543 D.P.N. (average maximum) and 594 D.P.N. (peak). These values are comparable with those obtained in the cruciform tests.

There is an indication that the hardness values for weld three are greater than those obtained for weld one; a higher cooling rate may be anticipated in the former case as explained later. The same is true of the fact that hardness values for the vertical leg tend to be less than those obtained for the horizontal leg. A somewhat higher cooling rate, and therefore a greater cracking tendency, is to be expected for the horizontal leg.

Discussion

To explain the severity of the cruciform test it is necessary to evaluate separately the various factors involved; i.e., hydrogen level, cooling rate and stress.

It has been shown that the cruciform test, unlike the controlled-thermal-severity test, provides opportunites for hydrogen-migration effects between neighboring welds.

* Thermal Severity Number (T.S.N.) for a particular joint is given by the total number of heat-flow paths in units of 1/4 in. of thickness. The thermal severity of the weld must, of course, also take into account the heat input.

† According to previous data,[4] this change in fillet size was expected to give the desired cooling rate.

This results in a cumulative effect of hydrogen and, therefore, greater severity with the former test.

Similar hydrogen-migration effects could presumably occur in other situations involving welds in close proximity; e.g., multirun deposits, crossed welds, etc. Further examination of this possibility might be well worth while.

"Restraint" is a term which is much used in discussing weldability, but rarely defined. The term "unrestrained" is widely used to describe the case of a surface bead or that of a joint between two small plates free to move, in spite of the fact that some mild restraint and some stresses are always present. This seems acceptable. The term "restrained" should therefore mean the extent to which the natural contractions of the welded joint are hindered.

From this point of view, Fig. 6 shows some fillet welds with varying degrees of restraint. Clearly the degree of restraint for the test welds of the controlled-thermal-severity test is greater than that obtaining in any of the welds of the cruciform test. Moreover in the case of weld number three of the cruciform test, the plates are only lightly tacked at the extremities; it is therefore laid down in an almost completely unrestrained condition. It is this weld which exhibits most cracking in the cruciform test.

Since weld three is unrestrained, and weld four is only partly restrained, the thermal contraction of weld four, characterized by a turning movement as shown in Fig. 5a, results in a stress which is shared between welds three and four. From this point of view, the stress developed should be less than that obtained in the controlled-thermal-severity test. However, this simple analysis is insufficient.

In the controlled-thermal-severity configuration, more heat will pass from the test weld into the top plate, than into the corresponding part of the bottom plate immediately beneath the top plate (see Fig. 5b). Consequently, the top plate will extend toward the weld, compressing the latter while it is still plastic, so that, on cooling, a tensile stress across the weld would result. The value of this stress will be related inversely to the total length of metal, which must elastically sustain this stress, i.e., in this case, the width of the top plate. The same mechanism will occur with the cruciform assembly and will result in higher stresses, since the length sustaining elastic stress (thickness of the plate) is considerably less. In addition, the mechanism is inhibited in the controlled-thermal-severity test, because the top plate is partly restrained with respect to horizontal movement, by the anchor welds and by the central bolt.

As a result of these considerations, the authors believe that higher contraction stresses are set up in the cruciform test, again resulting in greater severity.

The cruciform test is also thermally quite severe. Assuming a plate thickness of $^1/_2$ in., for the first two welds the thermal severity number (T.S.N.) is 6, since the lower member is only attached by tack welds at its extremities. For the second two welds, the thermal severity number is 8, corresponding to a bithermal test weld on 1-in. thick plate with the controlled-thermal-severity test. Figures 7a and 7b illustrate the heat-flow conditions for welds one and three and this makes clear the reason for the difference in thermal severity of the two welds. To a first approximation, welds two and four are equivalent from this point of view to welds one and three respectively, though in practice the cooling rate probably increases in stepwise fashion for the four welds, due to the increasingly complex heat-flow pattern.

It might be asked why cracking does not occur in weld two, since hydrogen can presumably migrate from weld one. The answer is believed to be that, in this case, the thermal severity of weld two is lower than that of welds three and four.

An important point is that the thermal severity of welds three and four will normally be greater, for equivalent plate thickness, than that of welds in the controlled-thermal-severity test.

In comparing the cruciform test with the controlled-thermal-severity test, the greater severity of the former rests on a combination of three factors:

1. Greater effective hydrogen level.
2. Higher cooling rates (for equivalent plate thickness).
3. Higher contraction stresses.

The relative importance of these factors remains to be assessed. From a practical point of view, it would be unwise to ignore the cruciform test in assessing the weldability of a given weld-steel combination, particularly in those cases, common in structural work, where joints similar to the cruciform joint occur.

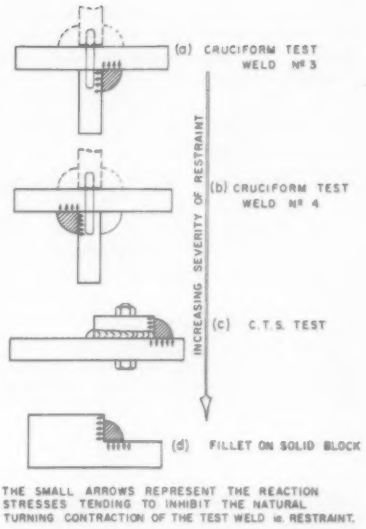
(a) CRUCIFORM TEST WELD Nº 3
(b) CRUCIFORM TEST WELD Nº 4
(c) C.T.S. TEST
(d) FILLET ON SOLID BLOCK
INCREASING SEVERITY OF RESTRAINT
THE SMALL ARROWS REPRESENT THE REACTION STRESSES TENDING TO INHIBIT THE NATURAL TURNING CONTRACTION OF THE TEST WELD ie. RESTRAINT.

Fig. 6—Degrees of restraint

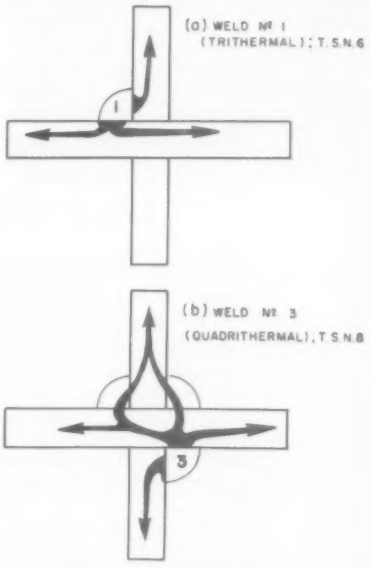

Fig. 7—Heat-flow patterns in cruciform test

Conclusions

(1) The work has confirmed that, with comparable cooling rates, the cruciform test is more severe than the controlled-thermal-severity test.

(2) The cruciform test should be considered for weldability testing in critical applications, since it represents conditions commonly occurring in structural work.

(3) The results suggest that hydrogen migration occurs between the adjacent welds of the cruciform test, resulting in a higher effective hydrogen level.

(4) It might be worth while to investigate the possibility of similar

hydrogen-migration effects in other situations involving welds in close proximity; e.g., multirun deposits, crossed welds, etc.

(5) The greater severity of the cruciform test is due to a combination of these factors:

(*a*) Higher effective-hydrogen level.
(*b*) Higher cooling rates (for equivalent plate thickness).
(*c*) Higher contraction stresses.

References

1. Cottrell, C. L. M., and Lane, P. H. R., "Correlation of Weldability Tests with Structural Joints. Part I—Investigations with Tests of the Restrained Fillet Type," *Weld. Res. (U. K.)*, **6**, 2–12 (Feb. 1952).

2. Cottrell, C. L. M., and Jackson, M. D., "Correlation of Weldability Tests with Structural Joints. Part II—Investigations with Unrestrained Fillet Tests and Structural Joints," *Ibid.*, **6**, 31–42 (April 1952).

3. Cottrell, C. L. M., Jackson, M. D., and Purchas, J. G., "Correlation of Weldability Tests with Structural Joints. Part III—Investigations with the Controlled Thermal Severity Test," *Ibid.*, **6**, 50–57 (June 1952).

4. Cottrell, C. L. M., Winterton, K., and Bradstreet, B. J., "The Weldability of High-Tensile Structural Steels," B.W.R.A. reprint from Ministry of Supply Report W.R. (D) 1/55, 1956, May, pp. 1–79.

5. Cottrell, C. L. M., "Controlled Thermal Severity Cracking Test Simulates Practical Welded Joints," THE WELDING JOURNAL, **32** (6), Research Suppl., 257-s to 272-s (1953).

6. Anon, "Cooperative Investigation of the Reproducibility of the C.T.S. Weldability Test for Low-Alloy Steels," Report Commission IX 213–58 International Institute of Welding, 1958.

7. Weiss, S., Ramsey, J. N., and Udin, H., "Evaluation of Weld Cracking Tests on Steel Armor," THE WELDING JOURNAL (7), Research Suppl., 348-s to 356-s (1956).

8. Anon, "Procedure; Armor Plate Crack Sensitivity Test," Research Group, Ordnance Advisory Committee on Welding of Armor.

9. Herres, S. A., and Woodward, P. E., "Welding of High Strength Constructional Steels with Ferritic Electrodes," THE WELDING JOURNAL 25 (10), Research Suppl., 646-s to 657-s (1946).

10. Herres, S. A., "Practical Importance of Hydrogen in Metal-Arc Welding of Steel," *Trans. ASM*, **39**, 162–188 (1947).

11. Winterton, K., and Cottrell, C. L. M., "Evolution of Hydrogen from Weld Metal," *Metallurgia*, **49**, 3–7 (Jan. 1954).

12. Anon, "Determination of Total Hydrogen Contents of Weld Metal—A Report of Commission II—Arc Welding," IIW/IIS-8–58, Vol. 4, No. 10, Oct., pp. 2–8.

13. Flanigan, A. E., "An Investigation of the Influence of Hydrogen on the Ductility of Arc Welds in Mild Steel," THE WELDING JOURNAL, **26** (3), Research Suppl., 193-s to 214-s (1947).

Some of the Educational Aspects of the Welding Research Council

The Council may be looked upon as an Educational enterprise. Its educational activities are of a varied nature.

The most obvious and in the long run, perhaps the most important of its activities is the by-product education of young engineers and scientists. The Council favors the placement of most of its project research programs in the universities of the U. S. and Canada. These funds help subsidize the graduate training of quite a number of engineers and scientists who might otherwise have chosen other fields of endeavor. This gives Industry and Government a greater supply of trained young men in the welding and closely allied fields. The Professors in charge also broaden their own experience in the supervision of these projects and in their contacts with industry representatives.

Through its established methods of procedure in most instances, hypothesis and "theory" are developed in advance of the conduct of experimental programs. Research work is then planned to prove, modify or extend such hypothesis and theory. In this way the amount of experimental tests are reduced and the results are made more widely applicable. However, as often happens, when a plausible hypothesis is developed, engineers serving on committees begin to utilize such hypothesis and theory long before all the experimental evidence is secured.

Engineers and representatives of code writing bodies who serve on committees are able to follow the work and analyze the test results thus hastening the day for the acceptance and utilization of the test results. Such direct and indirect education of committee members is considered to be of great significance.

One of the final steps in the "educational" program is the actual publication of the results thus making them widely available both here and abroad.

Quite often some of the reports and books published by the Council become text books in Universities in connection with Graduate and Undergraduate studies.

Effect of Magnetic Field on Transfer Characteristics of Particles in an Electric Arc

Transfer characteristics of metal particles under arc-blow conditions can be controlled by balancing the magnetic forces acting on the arc or offsetting their effects

BY PETRO SHAJENKO

ABSTRACT. Research was performed on transfer characteristics of particles within an electric arc in the presence of a magnetic field as related to metal-arc welding. The nature of the forces involved and the conditions under which particle transfer takes place was studied.

A new hypothesis for explaining metal transfer phenomena is proposed. This hypothesis explains observed phenomena and was successfully applied in overcoming arc blow in metal-arc welding.

Introduction

The transfer characteristics of charged particles in an electric arc under the influence of electric and magnetic fields have been extensively studied by many investigators;[1-4] however, the major concern in this investigation was the study of uncharged particles in the arc.

The impetus to initiating this investigation was the "arc blow" difficulty encountered in arc welding of heavy ferritic sections. Arc blow refers to a condition in which the welding arc is deflected from the desired target resulting in poor welding.

Many methods have been used by many people to counteract arc blow including: changing ground locations, using split grounds, using welding rods of small diameter and with uniform coverings, maintaining smaller welds, making narrow stringer welds, using permanent magnets, demagnetizing the plates to be welded, using specially designed magnetic shunts, using a-c current, etc.

The many apparently unrelated methods used to relieve arc blow indicated lack of a working hypothesis relative to arc-blow-producing phenomena. It was evident that not only the arc but also the metal transfer was affected by arc blow, but the manner in which arc blow affected metal transfer was not clearly understood. The problem was further complicated because of the meager knowledge available on the subject of metal transfer during welding.

This paper presents a hypothesis which explains the observed phenomena associated with arc blow.

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Problem Study

During the investigation of magnetic arc blow it was observed that the metal transfer from one electrode to another was affected by the presence of a magnetic field. This could not be attributed to the direct interaction between the magnetic field and weld metal; however, it was assumed that the magnetic field in some way affects metal-transfer forces. Subsequent investigations based on this assumption provided information needed for better understanding of the transfer characteristics of uncharged metal particles in the welding process.

In this investigation, two ferritic metal plates of $^1/_2$-in. thickness were used. Each plate was wound with 120 turns of No. 12 wire and connected to a d-c variable-voltage reversible-polarity power supply. Magnetic-field density in the air gap between welding plates was measured prior to welding with a flux meter.

The following parameters were controlled:

(*a*) Magnetic-field density in air gap.
(*b*) Direction of the magnetic field.
(*c*) Welding-rod material: ferritic and austenitic.

Fig. 1—Good weld

(*d*) Welding-rod covering.

Welding was performed using covered ferritic electrodes $^1/_4$-in. diameter. A constant welding current of 240 amp was maintained, while the magnetic-flux density was gradually increased from 0 to 550 gausses.

At zero field density in the air gap, good welds were produced and no arc blow was noticed (Fig. 1). As plates were gradually magnetized, the arc blow first became noticeable at flux densities of about 160 gausses. The welding arc was deflected from the target, and heavier-than-usual spattering of metal was evident. The difficulty experienced at this density was found to be dependent on the direction of arc deflection and was experienced only when the arc was deflected opposite to the direction of welding. As flux density was further increased to 320 gausses, severe arc blow was encountered. The arc was intermittently extinguished with metal spattering prevalent and welds of poor quality and appearance were produced (Fig. 2).

Investigations were made during welding with flux densities in the air gap above 500 gausses. Under this extremely severe condition,

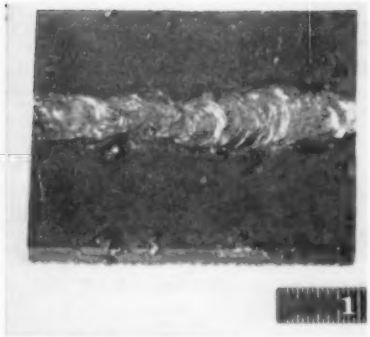

Fig. 2—Weld produced in presence of magnetic arc blow

the following phenomena were evident: (*a*) Metal spattering was in the direction of arc blow. (*b*) Metal particles were projected considerable distances. Particles of $^{3}/_{16}$-in. diam were projected distances as great as 4 ft. (*c*) The welding rod was consumed on the side to which the arc was deflected.

Arc blow was experienced with ferritic and austenitic electrodes. It is of interest to note that the arc-blow effect was produced when welding with a rod from which the covering had been removed on one side and with no magnetic field in the air gap. In this case, also, the arc became unstable and the metal spattering was directed from the bare side of the electrode.

To get a better view of the arc with and without arc blow, 16-mm moving pictures were made at 500 frames per second. Figure 3 shows welding without arc blow. Note limited and random metal spattering. The arc was concentrated at the target and the welding rod was consumed evenly at its end with covering touching the weld.

When the magnetic flux was adjusted to 480 gausses in the air gap, heavy arc blow resulted (Fig. 4). The direction of metal spattering can be seen clearly. The arc was dispersed and deflected from the target. The welding rod was consumed over $^{3}/_{4}$ in. on one side, thereby effectively increasing the arc length. No weld deposit could be made at this field density.

Based on these observations, the following areas were investigated: (*a*) The effectiveness of compensating magnetic fields. (*b*) The possibility of preventing unequal consumption of the welding rod by rotation.

Since an electromagnet can be used to produce and to control arc blow, it was convenient to study the arc behavior when an arc-blow-producing magnetic field was compensated with an opposing magnetic field. To accomplish this, a permanent magnet of 3-lb weight and 310 gausses was used to create the opposing field. The magnet was placed across the air gap between two ferritic metal plates previously magnetized to produce 320 gausses in the air gap. The compensating effect of the permanent magnet on the arc was readily noticeable, although satisfactory conditions for welding were difficult to establish. This was because: (*a*) the magnetic field produced by permanent magnet is localized by magnet location; therefore, the progressing arc is subjected to a varying magnetic field. (*b*) The flux density varies throughout the gap.

A detailed study of field interaction and resulting effect on the welding arc was made using test equipment shown in Fig. 5. The arc can be thought of, electrically, as a flexible extension of the welding rod; therefore, it was simulated by a conducting rod extending into a mercury pool. The mercury pool was used to provide the electrical connection at one end of the rod and in order to permit rod movement under magnetic deflecting forces. Strain gages were mounted on the welding rod to sense components of deflecting force on the rod from which the amplitude and directions of that force could be determined. Signals from associated bridge circuits were indicated on zero-centered microammeters. The polarity and magnitude of magnetism in the air gap were controlled with the magnetizing coils shown.

Measurements were made of the deflecting force on the rod while carrying 120 amp as the flux density in the air gap was varied in steps of 100 gausses, ranging from 0 to 500 gausses. These values are average since the field density varied across the 10-in. wide plate. Variations were as high as 68 gausses.

The deflecting force acting on the rod is proportional to the current flowing in the rod, field density in the air gap and rod length effectively below the mercury surface. The direction of the deflecting force is perpendicular to the plane of the current flow and magnetic field in the air gap.

Assuming the rod to be perpendicular to the two rectangular welding plates as shown in Fig. 5 and the rod current to be perpendicular to the magnetizing field, the direction of the deflecting force should be along the air gap. However, measurements revealed deviations from this direction of as much as 18 deg with 100 gausses in the air gap. At 500 gausses, the deviation was negligible. This is because, at low flux density, the magnetic field due to rod current significantly contributed to the total magnetic field, but at high flux density the magnetizing field is predominant.

Ground location is of considerable importance at magnetic field densities below 160 gausses. With a specific ground location, it was possible to completely balance the rod deflecting force.

In an attempt to balance magnetizing fields at the five field densities cited with a permanent magnet, it was found that, in each

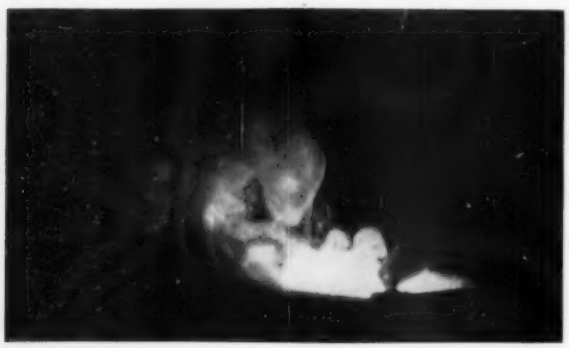

Fig. 3—Normal welding

Fig. 4—Welding in presence of magnetic arc blow

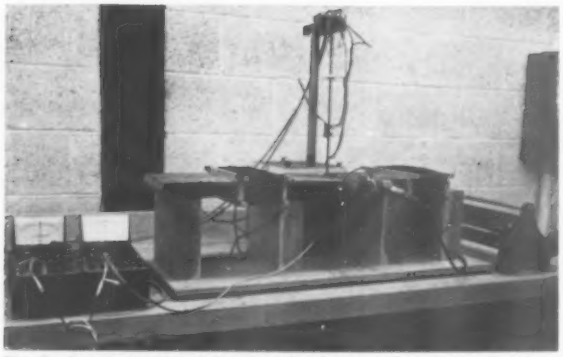

Fig. 5—Apparatus for detecting the force acting on arc due to interacting magnetic fields

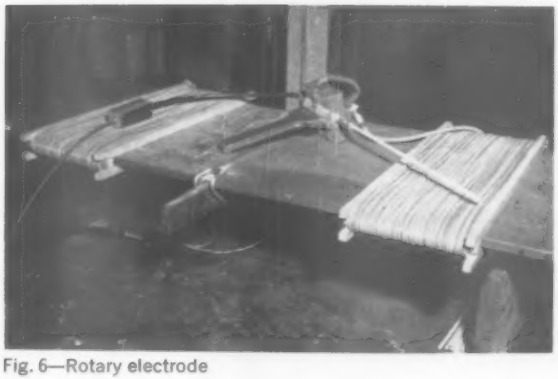

Fig. 6—Rotary electrode

case, only at one particular location of permanent magnet, was it possible to produce balance. Also, it is necessary that the field of the permanent magnet be opposite in polarity to the magnetizing field.

In order to overcome these difficulties, a d-c electromagnet* was designed which provided a controllable magnetic-field strength of reversible polarity utilizing a Wheatstone-bridge type control unit. Fixed resistors in the control circuit were of 25-amp capacity and 0.45 ohm each. The electromagnet consisted of 320 turns of No. 12 wire wound on a ferritic core. With a variable resistor (15 ohms, 25 amp) adjusted to the balanced position, no current flows through the electromagnet coil. The polarity of the electromagnet can be changed by adjusting this resistor to either side of the balance position. Increasing the bridge unbalance increases the magnetic-field strength. Because the electromagnet produces a field of easily controlled magnitude and polarity, any field variations about the rod could be balanced. Utilized in actual welding operation, this electromagnet effectively balanced magnetizing fields up to 550 gausses. At balanced position the arc was stable, the rod was consumed evenly and there was normal metal transfer producing good weld.

In order to study the effect of uneven consumption of the welding rod, a welding gun* was fabricated to rotate the rod during welding (Fig. 6). The welding plates were gradually magnetized from 0 to 480 gausses in the air gap. Welding was started with nonrotating electrode. As the magnetic field was increased to approximately 200 gausses, arc blow was encountered and directed spattering of metal noticed. When the welding rod was rotated, welding was improved. A further increase of flux density required shortening of the arc. Rod rotation permitted shortening the arc to a minimum without the rod sticking to the plates. A gas layer maintained between the welding rod and the welding plate offers electrical resistance which compensates for shortening the arc.

Uneven consumption of the welding rod and all consequent effects were eliminated by rod rotation. It should be noted that good results using a rotating electrode were not immediately attained. During normal welding, with no arc-deflection forces present, the operator can maintain a relatively long arc; however, when arc deflection forces are present, as in cases where rotating electrode would be used, it is important that a short arc be maintained. This requires the operator to hold a short arc at all times, as an increase in arc length will result in arc blow. Extremely heavy arc blow requires that welding be in the direction of arc blow.

Figure 7 shows comparison of welding rods used under different conditions. It should be noted that rod No. 2 used in welding without arc blow was evenly consumed. The rod and covering during arc blow are consumed along the side of the arc blow (rods 3 and 4). Rod No. 5 was used with magnetic arc blow compensated by electromagnet and No. 6 by rotating welding rod. Rod Nos. 5 and 6 are similar in appearance. Figures 8 and 9 illustrate welds and their corresponding radiographs, respectively. Welds made using electromagnetic compensation (*B*) and rotating electrode (*C*) to oppose arc blow are compared with weld made when arc blow was present (*A*). Weld (*A*) is not acceptable, weld (*B*) is solid and weld (*C*) is rated standard A. This shows that arc blow can be successfuly opposed by use of an electromagnetic compensation or a rotating electrode in practical applications.

Theoretical Considerations

Information obtained through above investigations will now be used to describe the metal transfer and arc-blow phenomena in welding. Let us study the welding arc in terms of well established steady-state electric-arc theory considering the fact that arc voltage, current, length and surrounding conditions are varying during welding and that such variations influence arc stability.

The welding arc is a low-voltage, high-current, self-maintained gas discharge through which electrical energy is transferred into useful welding heat. The mechanism of regeneration of electrons to sustain the arc was first suggested by J. J. Thompson[1] as thermionic in nature. The temperature of the welding arc is estimated to be close to 6000° C.[5] The intense heat provides free electrons with sufficient energy to escape from the cathode into space. The relation between the thermionic emitted current and the temperature can be expressed by Dushman's equation:[6]

$$I_{TH} = AT^2 \cdot e^{-b_0/T} \text{ amperes} \quad (1)$$

Where $A = A_0 F$, F is the area of the emitting surface in square meters, A_0 is a constant, T is the temperature of the emitter in degrees Kelvin, $b_0 = 11.600 E_w$ and E_w is a work function of the emitter in electron volts.

The large amount of emitted electrons would build a negative space charge in the vicinity of the cathode if positive ions in sufficient number were not present. The number of positive ions required for neutralization is much smaller than the number of electrons present, because the space charge is inversely proportional to the velocity of drift and the velocity or

* Patent pending.

drift for positive ions is smaller than for electrons.[7]

There must be additional positive current of sufficient density just outside the cathode to provide the required positive space charge to permit the escape of electrons. A supply of positive ions in this amount is provided by thermal ionization of gas between electrodes. The degree of ionization can be calculated after SAHA's equation:[8]

$$\log \frac{X^2}{1 - X^2} \cdot p = -\frac{U}{4.57 \cdot T} + 2.5 \log T - 6.5 \quad (2)$$

where U ($U = 2.29 \cdot 10^4 \cdot V_i$) is the energy required for ionization in calories per gram molecule, V_i is effective ionization potential in volts, X is fraction of ionized molecules and p is the pressure in atmospheres.

The movement of a charged particle across the arc accelerated by the electric force is the arc current. The force F_e acting on the charged particle in an electric field of intensity E, which is due to voltage applied across the arc, is equal to:

$$F_e = q \cdot E = m \frac{dv}{dt} \quad \text{(newtons)} \quad (3)$$

Where q is the charge of particle in coulombs, m is the mass of charged particle in kilograms, $\frac{dv}{dt}$ is the acceleration in meter/sec^2.

The welding arc is divided into three regions with associated voltage drops: cathode fall, plasma and anode fall. The welding heat, which is generated in proportion to the voltage drops in each region and the current flowing through it, melts the metal to be welded forming a molten pool on its surface and melts the top of the welding rod. Molten metal is transferred from the rod to the molten pool and deposited there.

Several theories have been proposed regarding the metal transfer. They could be grouped around two basic concepts: globular metal transfer and metal transfer in form of minute particles.

O. H. Escholz has advanced a theory that metal is transferred mainly in liquid form.[9] Under welding heat, the top of the welding rod melts forming globules which, due to continuous growing, make contact with the pool on the plate, whereupon the forces of adhesion and surface tension of the plate overcome combined forces of cohesion and surface tension acting to hold the globule to the electrode surface.

On the other hand, L. J. Larson[10] believes that metal transfer takes place in the form of small particles about 0.001 in. diam with occasional particles over 0.010 in. passing across the arc. These particles move at speeds up to 120 mph. It takes 0.002 second for a large particle and 0.0001 second for small particles to cover the distance between electrodes. This means that particles are transferred without short circuiting of the arc. Globular transfer of metal necessarily requires short circuiting of the arc each time the globule transfers.

Arc study, however, cannot fully account for both concepts. During welding, the arc is short circuited but at a much lower rate than would be necessary for globular transfer. Although Larson omits further explanation, his data are in close agreement with that obtained in this investigation. From this study it is possible to picture more clearly the metal-transfer mechanism.

As mentioned before, the welding heat is generated in proportion to the voltage drops along the welding arc. On the electrode surfaces, it localizes at cathode and anode spots which cover comparatively small areas and, therefore, the temperature of the material at those spots may rise above boiling point. The spots are in continuous movement on the electrode surface under the influence of electromagnetic, thermodynamic and mechanical forces; the speed of this movement influences the spot temperature. The temperature is much

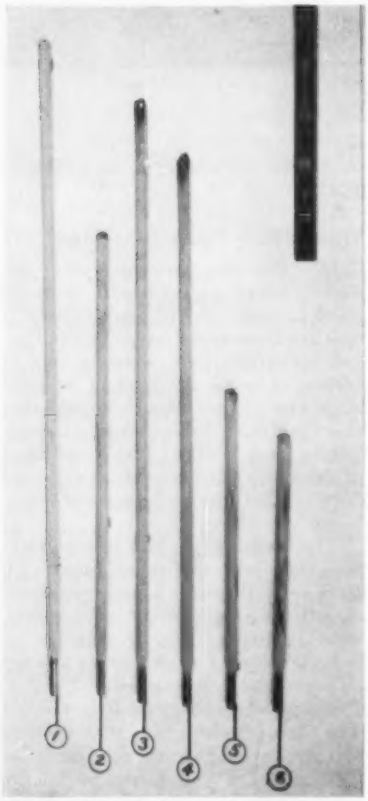

Fig. 7—Welding rods as affected by magnetic arc blow. (1) Welding rod not used. (2) Welding without arc blow. (3, 4) Welding with arc blow. (5) Welding with use of compensating electromagnet. (5) Welding with rotary electrode.

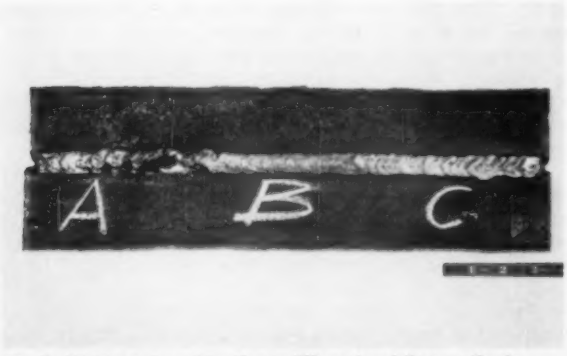

Fig. 8—Weld produced by three different welding methods. (A) Heavy arc blow. (B) Use of compensating electromagnet. (C) Use of rotary welding rod.

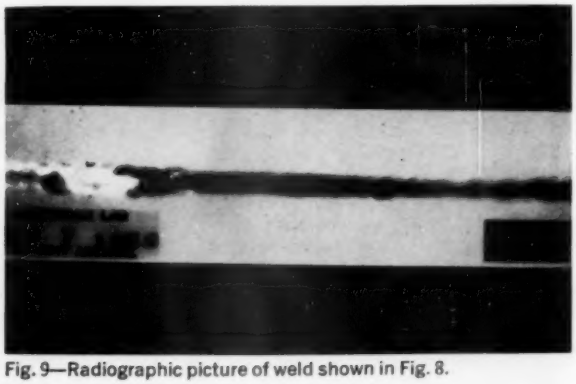

Fig. 9—Radiographic picture of weld shown in Fig. 8.

higher at the welding rod than on the metal plate because the spot on the welding rod has less area about which to move and the welding rod has less mass to dissipate heat. In turn, the higher temperature makes the arc more attracted to a particular spot on the electrode surface, causing deeper local penetration. Metal in the immediate vicinity of the spot is in a molten state. The tremendous release of welding heat over a small area on the welding rod causes explosions which project the molten metal away from the tip of welding rod.

The magnitudes of these explosions are random, resulting in random distribution in speeds and sizes of metal particles. Some of them will be of sufficient size to short circuit the arc. Higher temperatures produce stronger explosions, resulting in smaller and more energetic metal particles which are directed from the surface of the rod tip to the molten pool on the metal plate. Heavy bombardment of the metal pool by these particles creates craters, the depth of which is a good measure of penetration and quality of weld. Also a considerable amount of the metal transfer is due to subsurface explosions within the tip of the welding rod. Under intense welding heat, the gas available in the tip of the rod due to evolution, vaporization, decomposition, etc., causes explosions that accelerate metal particles.

At lower temperatures, the magnitude and number of explosions decrease and other metal transfer forces, such as gravity and capillary attractions, become predominent. This type of metal transfer is experienced by welding with bare electrode.

The welding-rod covering, in addition to preventing oxidation, concentrates heat energy at the tip of the welding rod by providing insulation, thereby maintaining the tip at a much higher temperature, producing better metal transfer. The melting rate of the covering is lower than that of filler metal, maintaining a concave shape in the welding-rod tip. This has a focusing effect on metal particles. Only high-energy randomly directed particles are able to escape the molten pool under these conditions, resulting in normal spattering.

This point of view readily describes overhead welding where gravity and capillary attraction without direct contact between electrodes is not possible. In overhead welding, higher currents and shorter arc length are desirable, since they both contribute to the magnitude of explosions. Forces of lower magnitude will be sufficient to lift metal particles across shorter arcs, which increases welding speed.

The preceding analysis explains observed phenonema during arc blow. In summary, the welding arc, being a gaseous current-conducting medium, can be affected by certain mechanical, thermodynamic and electromagnetic forces which shift the arc along its length in direction of these forces. This results in shifting of spots on the electrode surfaces. The spot on the welding rod will be shifted from the tip to the exposed side. Unequal consumption of the welding rod destroys the heat concentrating properties of the covering resulting in a melt of lower temperature, weaker explosions, larger metal particles and a longer arc. Longer arcs result in larger target areas on the plate, producing a melt of insufficient temperature for proper penetration of less energetic and larger metal particles. Under this condition, the metal particles do not fuse to the molten metal of the plate but rebound causing spattering and poor weld. The direction of spattering is determined by the shape and orientation of the consumed welding-rod-tip surface being projected in a direction perpendicular to it.

Reexamining the "quick fixes" reported in the literature in the light of these findings:

(*a*) The use of welding rod with smaller diameter may relieve arc blow because the arc length can be kept shorter with less consumption on the side of the rod, providing better heat concentration.

(*b*) The use of a welding rod with uniform covering may relieve arc blow because the arc may break through the lighter covering thus destroying the particle-guiding and heat-concentrating properties of the rod covering.

(*c*) The use of consumable-electrode welding prevented arc blow because the arc length is automatically kept short and the small electrode and higher current density used provide the higher temperature required for good welding.

(*d*) Maintaining a smaller pool may relieve arc blow because heat is concentrated in smaller area. The same could be said about making narrow stringer-weld melts.

The degree of effectiveness using these methods depends on the magnitude of arc-blow-producing forces. If they reach a certain level, these methods are useless.

Other methods used to relieve arc blow in practical applications are aimed at prevention or balancing of arc-deflecting forces. Mechanical and thermodynamic forces are sometimes very troublesome and, in general, can be eliminated easily. They are, in most cases, due to high wind velocity in the vicinity of the arc or due to improper temperature of welding material. It was found that the arc could be completely extinguished by air currents of approximately 1000 fpm and that preheating of welding materials before welding or eliminating air currents in vicinity of the arc in many cases will relieve arc blow.

Electromagnetic forces which produce arc blow, however, are more complex in their origin and in the way they effect the arc. The magnitude and frequency of occurrence of arc blow produced by these forces had led many to believe that arc blow is magnetic in nature and therefore, is generally called magnetic arc blow.

To discuss the effect of a magnetic field on the electric arc a simplified case will be assumed in which the electric and magnetic fields are perpendicular. A charged particle q (electron or positive ion) at rest will not be subjected to forces due to the magnetic field; however, when it moves at a velocity $\bar{V}$, it constitutes an electric current and is subjected to a magnetic force F_m:

$$\overline{F_m} = q \cdot \bar{V} \cdot \bar{B} \quad \text{(newtons)} \quad (4)$$

Where $\bar{B}$ is the magnetic-flux density in Webers per square meter. The direction of this magnetic force on a charged particle q is always perpendicular to its velocity $\bar{V}$ and, therefore, the charged particle assumes a circular path. The radius of curvature can be found from the mechanical analogy of a particle moving in a circular path with a constant velocity $\bar{V}$. The particle will accelerate toward the center of the circle with a magnitude of V^2/R, where R is the radius of the circle, then:

$$\frac{MV^2}{R} = qVB \text{ and}$$

$$R = \frac{MV}{qB} \text{ meters} \quad (5)$$

If both forces (electric and magnetic) act on the particles simultaneously, then:

$$\bar{F} = \bar{F}_e + \overline{F_m} = q(\bar{E} + \bar{V} \times \bar{B}) \quad (6)$$

The charged particle under the influence of this force will be deflected during transit.

The magnetic forces affecting the arc can be due to welding current, residual magnetism in welding plates and any externally imposed mag-

netic field. A magnetic field due to welding current exerts forces only when asymmetry of that magnetic field exists. Frequent causes of such asymmetry is a ground location, mass distribution around the arc and heterogenity in electrical properties of welded material.

Arc deflection due to welding current can be experienced with nonferritic as well as ferritic materials; however, the reluctance of the materials may determine deflection characteristics.

The lines of magnetic flux around the welding arc follow the path of least reluctance. Where a difference in reluctance exists, asymmetry of the magnetic field will result. An asymmetrical magnetic field around the welding arc causes arc deflection in both a-c and d-c welding; however, the changing magnetic field due to a-c welding current induces eddy currents in the welding plates which in turn produces fields neutralizing those due to welding current.[11]

This investigation revealed that arc blow is of minor magnitude when only magnetic fields due to welding current are present. It can be opposed comparatively easily by various techniques such as using balanced ground end strips, changing ground locations or changing the mass of magnetic materials, etc.

Arc blow severe enough to extinguish the arc is essentially due to interaction between the residual magnetism in the welding plates and magnetism due to welding arc current. Residual magnetism may be present in the plates in the as-received condition or may be introduced during subsequent operation such as lifting with electromagnets. Even though the magnetic-field density in each of the two plates may be low when separated large distances, the density greatly increases as the plates are brought into position for the welding operation.

From this it could be concluded that the only effective way of combating arc blow is to balance deflection forces or counteract their effect on the arc during welding. These principles were successfully incorporated in a controllable electromagnet and rotary electrode.

Summary

Filler metal is transferred across the arc in the form of small metal particles by explosive forces due to the tremendous release of heat energy on small areas on the tip of the welding rod and by subsurface explosions of minute gas enclosures. The magnitude of these explosions and the resultant size and speed of metal particles is random because of the random nature of the thermal transients and their distribution on the welding rod. At proper temperatures, metal particles are emitted at high speed from the molten surface of the welding rod and penetrate the molten pool on the plate, forming a fused weld. If temperatures are too low as a result of arc blow, particles are larger, less energetic and may rebound from the plate.

An electric arc, being a gaseous current-conducting medium, can be affected by a large number of forces; of these, electromagnetic forces are the most predominant in the metal-arc welding process. They cause instability, shifting and deformation of the arc (arc blow). Although electromagnetic forces have no direct effect on molten-metal particles in transit, they influence the transfer characteristics of these particles by affecting the arc.

The transfer characteristics of metal particles under arc-blow conditions can be controlled by balancing the magnetic forces acting on the arc or offsetting their effects. These principles were incorporated in a controllable electromagnet and a rotary welding rod which were successfully used in extreme laboratory conditions and in practical applications.

Acknowledgment

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References

1. Thompson, J. J., *Conduction of Electricity Through Gases.* Cambridge University Press (1903).

2. Darrow, K. K., *Electrical Phenomena in Gases*, Williams and Wilkins Co., Baltimore, Md. (1932).

3. Loeb, L. B., *Fundamental Processes of Electrical Discharge in Gases*, J. Wiley & Sons, Inc. (1939).

4. Winsor, L. P., and Loe, T. H., Properties of DC Arc in a Magnetic Field," *Communication and Electronics*, pp. 143–148 (May 1956).

5. Welding Handbook, 3rd ed., American Welding Society, p. 56.

6. Dushman, S., *Phys. Rev.*, **21**, 623 (1923).

7. Compton, K. T., "Theory of Electric Arc," *Ibid.*, **21**, 266–281. (1923).

8. SAHA, *Phil. Mag.*, **40**, 472 (1920).

9. Escholz, O. H., *The Welding Encylopedia*, 12th ed., 745–746 (1947).

10. Larson, L. J., *Ibid.*, 12th ed., 744–746 (1947)

11. Jennings, C. H., and White, A. B., "Magnetic Arc Blow," The Welding Journal, **20** (9) Research Suppl., 427-s to 436-s (1941).

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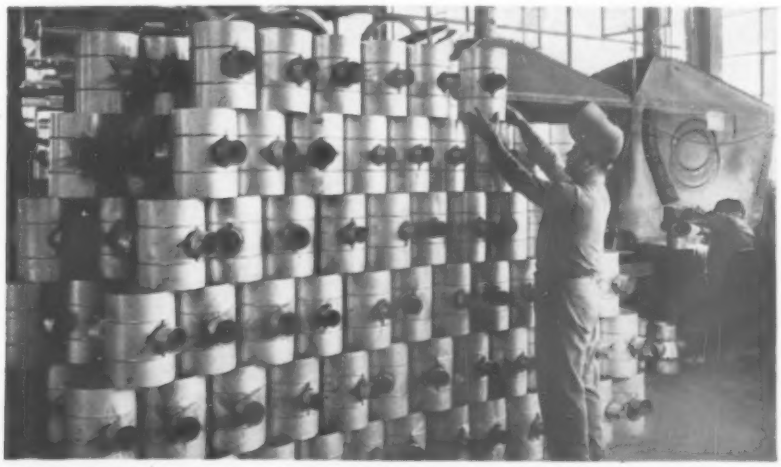

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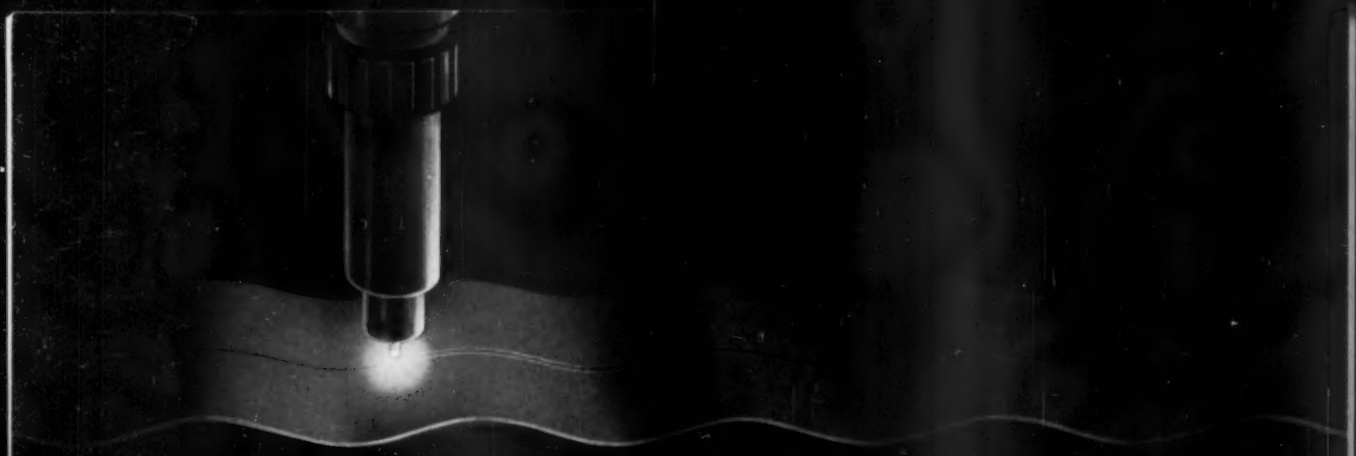

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